# Color Atlas of VETERINARY PATHOLOGY

SECOND EDITION

Edited by
J.E. van Dijk,
E. Gruys and
J.M.V.M. Mouwen

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An imprint of Elsevier Limited



First published 1982
Second edition 2007
Reprinted 2007, 2008

ISBN: 978-0-7020-2758-1

**British Library Cataloguing in Publication Data**
A catalogue record for this book is available from the British Library

**Library of Congress Cataloging in Publication Data**
A catalog record for this book is available from the Library of Congress

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# Foreword

Pathology is the diagnostic and conceptual basis for the practice of veterinary medicine and surgery. Ability to recognise, describe and diagnose animal disease, and to understand the pathogenesis of lesions are key attributes of the practising veterinarian. Recognition of gross lesions is essentially visual and lends itself well to photographic recording. The second edition of this Atlas continues an outstanding tradition of the Institute of Veterinary Pathology in Utrecht in producing high quality illustrations of both gross and microscopic lesions. This Atlas will remain an invaluable learning resource, in conjunction with other modes such as electronic databases and textbooks, for all those professionals who deal with animal disease: students, veterinarians, and pathologists at all stages of their continuing professional development.

A problem familiar to those involved in teaching veterinary pathology is the ideal of striking a balance between, on the one hand, understanding of disease processes in functional mechanistic terms and, on the other hand, the imparting of factual information about pathology that is appropriate to particular stages of professional development. Probably few individuals or institutions get the balance right consistently. In this second edition the authors provide synopses of the basic pathological processes that inform the spectrum of illustrated specific lesions in each of the major organ systems. In the view of this reader these synopses strike a good balance and should be particularly helpful for veterinary students whose courses are often overloaded with pathogenetic minutiae. The synopses will form useful starting points for those who need more detailed analyses of basic pathology mechanisms.

This Atlas is a continuing testimony to both the authors' experience in veterinary pathology diagnosis, research and teaching, and to their Institute's fine practice of photographic recording and accessioning of lesions both common and uncommon. This edition, like its predecessor, will be welcomed throughout the veterinary community of all those who learn and teach.

Emeritus Professor DF Kelly
Department of Veterinary Pathology
University of Liverpool

# Preface to the second edition

Twenty-four years have passed since the English edition of the Color Atlas of Veterinary Pathology was first published in 1982. After that Greek (1982), German (1983), Japanese (1983), Spanish (1984), Italian (1984) and French (1986) editions of the book came out.

We are still conscious of the need to preserve the original aim of understanding disease and disease processes. In the first edition this was defined as demonstrating how cellular pathology, inflammation, circular disturbance and neoplasia are expressed in the different organs and tissues. For this purpose again we have used examples of specific veterinary pathology without trying to give a survey of all the different diseases possible. To make this more clear the title of this revised edition has been extended with 'General morphological reactions of organs and tissues'. As this book is also intended to be used by students, we have added comprehensive general introductions to the different organs and organ systems. Finally, much new material has been presented, while the number of photographs has been enlarged.

We are grateful to all people who have contributed to the quality of this book. A special word of thanks to the 'Elsevier crew' i.e. Joyce Rodenhuis, commissioning editor, Rita Demetriou-Swanwick, development editor, Elouise Ball, project manager, Andy Chapman, designer and Elma Burton, who edited our introductions to the chapters. Harry J. Kurtz gave valuable advice to improve the English language.

J.E. van Dijk
E. Gruys
J.M.V.M. Mouwen

July 2006

Department of Pathobiology
Faculty of Veterinary Medicine
University of Utrecht
Utrecht, The Netherlands

# Preface to the first edition

This Color Atlas of Veterinary Pathology is intended for students of veterinary medicine. During the last two decades the knowledge of animal pathology has been extended overwhelmingly. At present an overcrowded curriculum puts great pressure on veterinary students. Including more and more bare facts in the undergraduate and graduate pathology courses must be avoided. Now, more than at any time, the main target of the pathology course to veterinary students must be the understanding of disease and disease processes. However, a certain amount of practical ability as well as some factual knowledge is required, since veterinarians, unlike physicians, are expected to do post-mortem examinations routinely.

Our aim was to create a photographic atlas which can be used together with the currently available textbooks of pathology. The text has therefore been kept short. It is expected that the atlas will also prove to be of interest and value to non-veterinary students engaged in pathobiology, and to postgraduate veterinarians working in laboratories, meat inspection or practice.

The organism exposed to the cause of disease can be affected in different ways, and reaction to the noxious influences and restoration of homeostasis are achieved by various means, which may involve structural alteration of organs, tissues and cells. Because organs, tissues and cells can be changed only in restricted ways, various diseases may result in the same structural changes, knowledge of which can contribute to the understanding of the functional disorder. As the understanding of disease and disease processes is the primary goal of pathology courses to veterinary students, this photo atlas is directed predominantly to the basic morphological changes seen in diseases of domestic animals.

The macro- and microphotographs, predominantly of domestic animals, are mainly from the collection of the Institute of Veterinary Pathology in Utrecht. This collection was started about twenty years ago by our mentor, the emeritus Professor S. van den Akker. We express our thanks to Prof. Dr. J. Hoorens, director of the Institute of Veterinary Pathology of the State University of Ghent, Belgium, for supplying some necessary photographs, which were absent from our collection (numbers 2-31, 3-1, 13-6).

Many people, both current and past members of the Institute, have contributed directly and indirectly to the contents of this book. Of the present-day technical staff especially H. Halsema, I. Heystek and J. Lek were involved in the preparation of the atlas.

We are much indebted to E.C. Firth for correction of the English translation.

J.M.V.M. Mouwen
E.C.B.M. de Groot

September 1982
Institute of Veterinary Pathology
Faculty of Veterinary Medicine
State University of Utrecht
Utrecht, The Netherlands

Chapter 1

# The hematopoietic system



## THE HEMATOPOIETIC SYSTEM

The hematopoietic system includes the lymphoreticular (e.g. mucosa associated lymphoid tissue (MALT), spleen and lymph nodes) and lymphoepithelial tissues and organs (e.g. Peyers' patches, thymus, tonsils and Bursa of Fabricius), and blood and bone marrow.

Its cellular components provide oxygen transport (erythrocytes) and protective responses to infectious and non-infectious agents (lymphoid cells, mononuclear phagocytic cells, granulocytes and supportive tissues).

The main patterns of reactivity of the hematopoietic system are:

- atrophy;
- filtration;
- hyperplasia;
- inflammation; and
- neoplasia.

In addition, degenerative changes of erythrocytes, circulatory disturbances and abnormal deposits may occur.

### *Atrophy*

In cachexia the hematopoietic tissue in the bone marrow can be displaced by gelatinous, almost translucent material, the *serous atrophy* of bone marrow.

(Non-)infectious agents can induce *atrophic* changes, either by 'exhaustion' of the response capacity of the tissue or as a direct or indirect effect on the effector cells. High levels of glucocorticoids may cause *lymphodepletion* in lymphoid tissues.

### *Filtration*

*Filtering* of lymph in the lymph nodes with deposition or processing of filtered material may reveal important information

with regard to processes in the drainage area of that lymph node. The same applies to the filtering of blood in the spleen.

## Hyperplasia

*Reactive hyperplasia* of hematopoietic tissue can expand into and replace fatty bone marrow. Mostly, the myeloid cell series is involved and the process will result in leukocytosis in the peripheral blood.

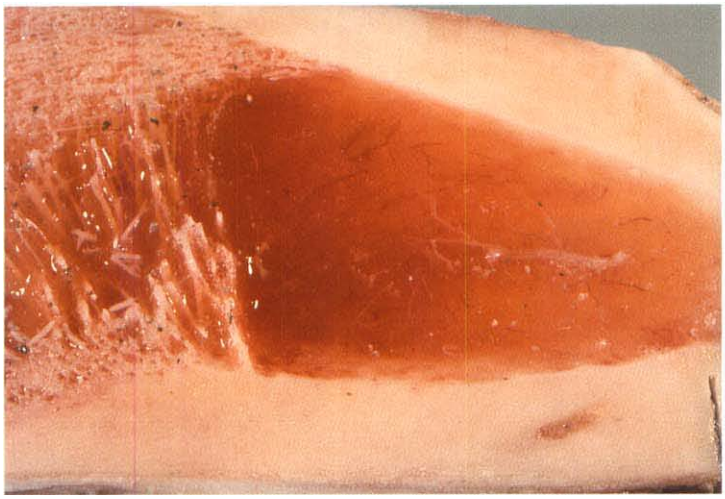
Because of the close relation between *adaptive reactivity* and *inflammatory reaction* these two processes are often difficult to distinguish, especially based on gross morphology. From a functional perspective, swelling of lymph nodes and spleen in the course of an inflammation is therefore described as *reactive hyperplasia*. Humoral immune reactivity is evidenced by B-cell hyperplasia with large secondary follicles and many plasma cells in the medullary cords of the lymph nodes, and cellular immunity evidenced by hyperplasia of the paracortical zones (lymph nodes) or periarterial lymph sheaths (PALS, spleen). Most hyperplastic reactions are non-specific in that they do not reveal the identity of the agent responsible.

## Inflammation

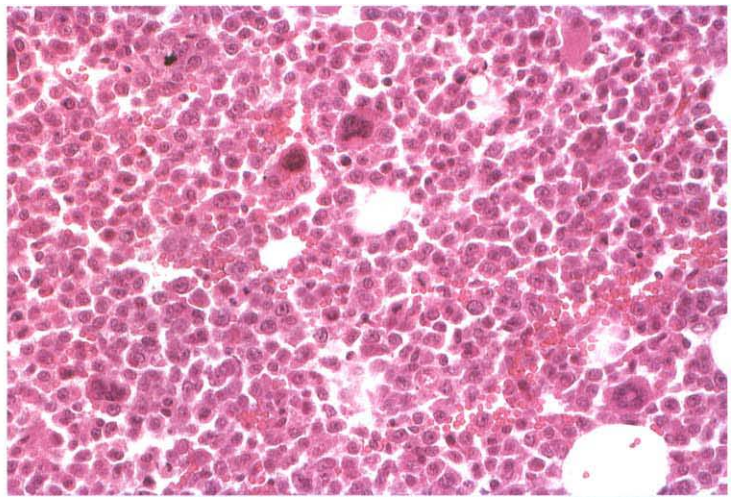
When characteristic inflammatory changes like suppuration, necrosis or caseation are visible in lymph nodes or spleen, *lymphadenitis* and *splenitis* are appropriate terms.

## Neoplasia

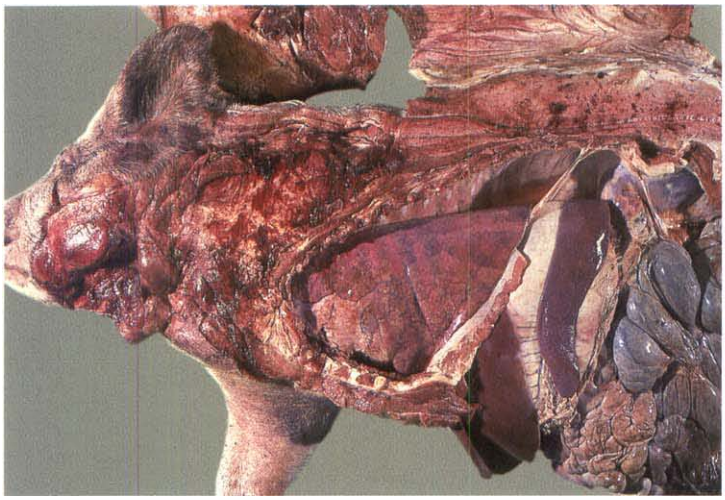
*Neoplasms* of the hematopoietic system are also relatively common in both companion animals and production animals and are classified according to their histogenetic lineage. The different types of malignant lymphoma and leukemia are the most frequent hematopoietic tumors. Characterization of tumor cell populations in companion animals is increasingly facilitated by immunohistochemical methods. In several species (e.g. feline, bovine, chicken, rat and mice) viruses can be responsible for tumorous proliferation of lymphoid cells or, less often, myeloid or erythroid cells.



**1-1** Serous atrophy
Bone marrow, dia- and metaphysis of femur. Red (blood forming) and yellow (fatty) bone marrow displaced by gelatinous and translucent material traversed by small blood vessels. Atrophy of hematopoietic tissue due to cachexia. Cow.



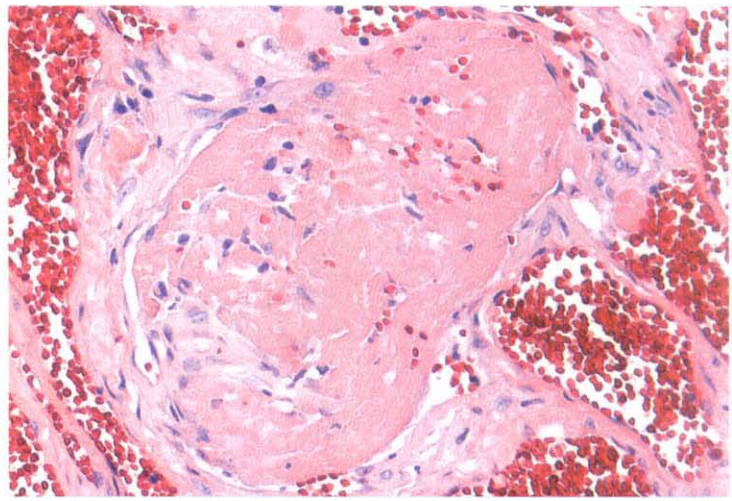
**1-2** Myeloid hyperplasia
Bone marrow, mid-diaphyseal area of femur. Increased number of immature myeloid cells (myeloblasts and megakaryocytoblasts), few normoblasts. Leukocytosis due to infection. Adult cat. HE.



**1-3** Methemoglobinemia
Brown discoloration of blood and tissue due to methemoglobin formation ($Fe^{++}$ replaced by $Fe^{+++}$). Nitrate (nitrite) poisoning. Pig.

**1-4** Blood clots
Concha. Random, loosely arranged meshwork of delicate fibrin fibrils, after settling out and coagulation of stagnant blood. In a neighboring vessel accumulation of leukocytes as a buffy coat between plasma and red clot. Horse. HE.

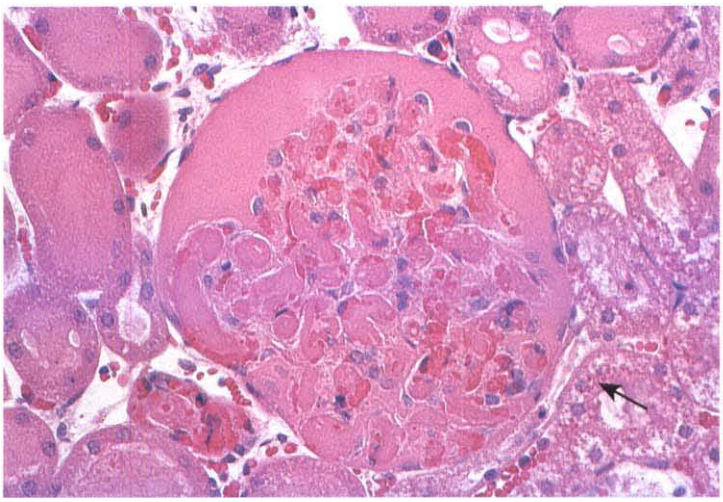
**1-5** Thrombus
Concha. Concentrically arranged, densely packed aggregations of fibrin fibrils, deposited in flowing blood. The thrombus is attached to the damaged arterial wall, and is covered by a red clot. Pseudomembranous rhinitis. Horse. HE.



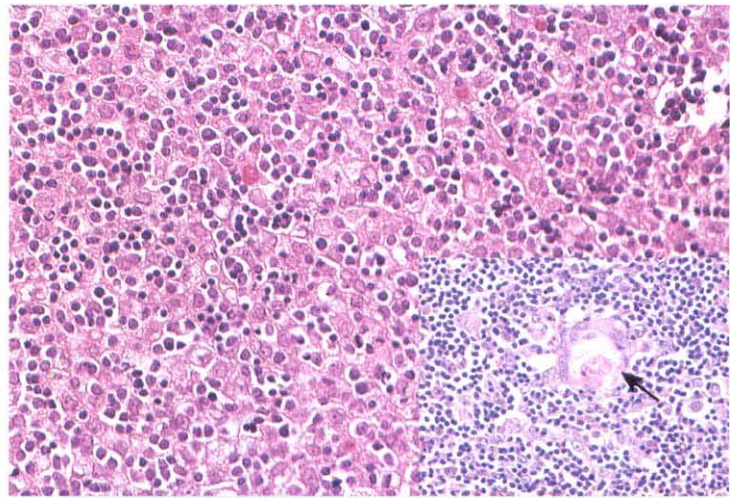
**1-6** Recanalization of thrombus
Skin. Surface of thrombus covered by endothelium. Formation of new canals lined by endothelium allowing some blood flow. Hemangioma. Dog. HE.

**1-7** Thrombocytopenic purpura
Skin. Many small hemorrhages. Defective hemostasis following immune-mediated destruction of thrombocytes by maternal antibodies in colostrum. Although primary plug formation by platelets is impaired, coagulation is still possible, preventing larger hemorrhages. Porcine thrombocytopenia purpura. Newborn piglet.

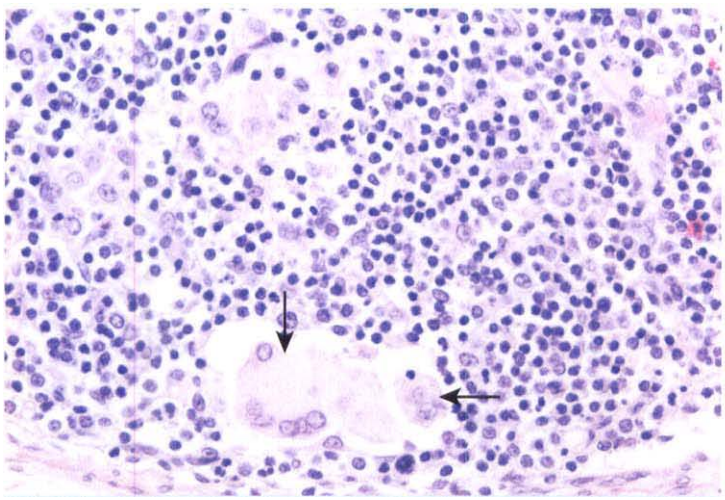
**1-8** Consumption coagulopathy and hemorrhages
Adrenal gland, sagittal section. Extensive cortical hemorrhages due to consumption of clotting factors and loss of platelets by disseminated intravascular coagulation (DIC). Hemorrhages of similar size may also be due to primary vascular damage (e.g. mulberry heart disease, Fig. 2-17). *Escherichia coli* endotoxic shock. Foal.



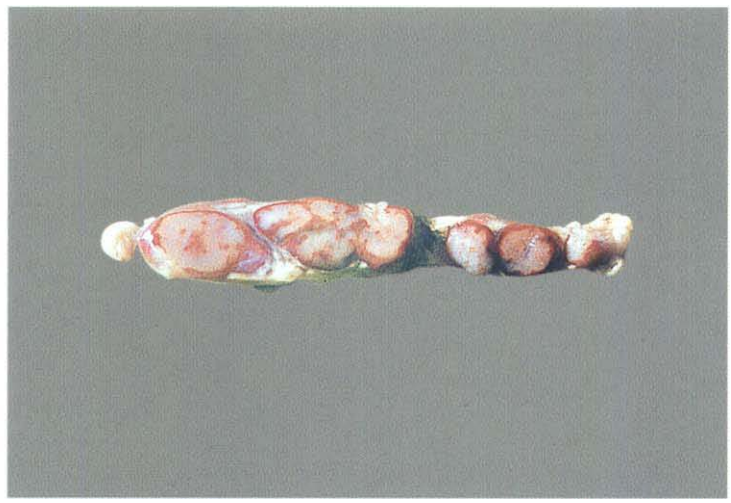
**1–9** Disseminated intravascular coagulation (DIC)
Kidney. Glomerular capillaries obstructed by hyaline microthrombi (platelets and fibrin), causing oliguria or anuria. Protein casts in Bowman's space and most tubules. Hyaline droplets, due to protein pinocytosis (cf. Fig. 4–16), in tubular cytoplasm (arrow). Acute tubular necrosis often occurs during DIC (see Fig. 4–7). Shock following experimental *Trypanosoma brucei* infection. Rabbit. HE.



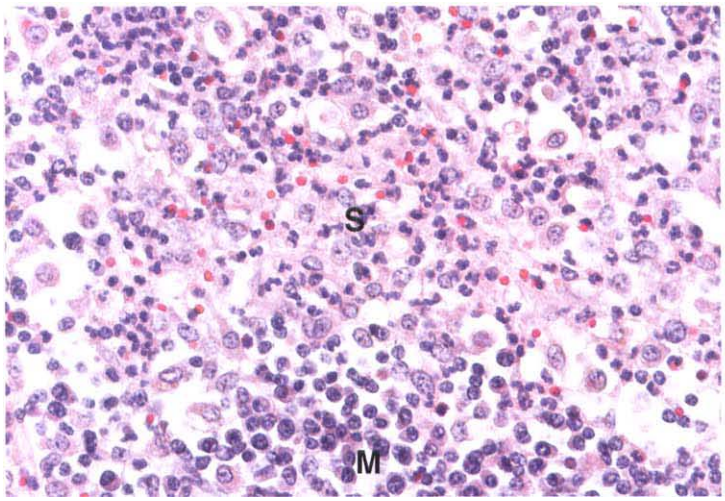
**1–10** Thymoma
Mediastinal tumor composed of epithelial cells with non-tumorous lymphocytes. Network of large, pale staining, epithelial cells sometimes resembling stromal cells; mature lymphocytes in meshes. Insert: epithelial cells arranged in fields as abortive Hassall's corpuscles (arrow) mixed with mature lymphocytes. Dog. HE.



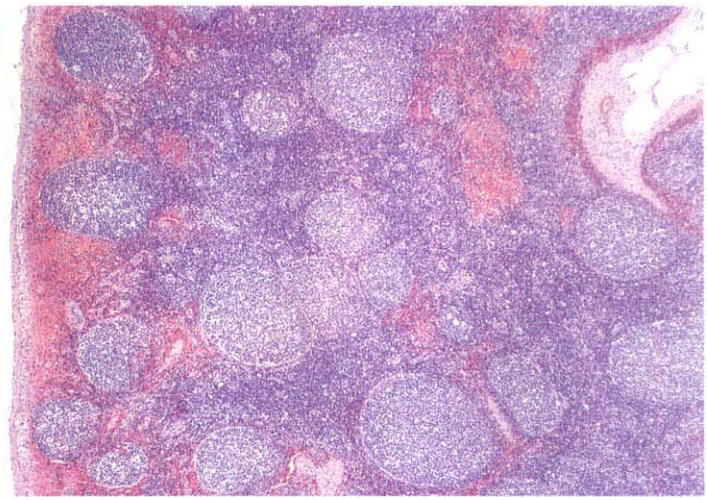
**1–11** Disease-associated lymphoid involution (atrophy)
Peripheral lymph node. Relative cell-poor cortical and paracortical areas containing increased numbers of (hypertrophic) macrophages several of which formed syncytial giant cells (arrows). Circo-virus infection: postweaning multisystemic wasting syndrome (PMWS). Pig, 3 months. HE.



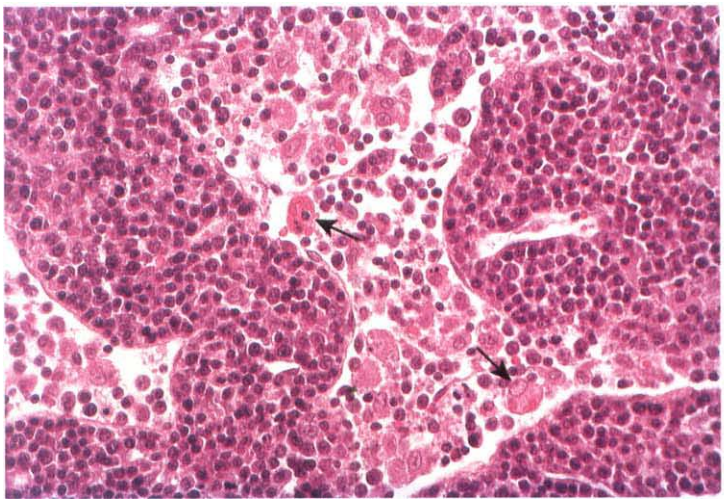
**1–12** Non-specific filtering of lymph
Lymph nodes, cut surface. Accumulation of erythrocytes in large peripherally located sinuses and paratrabecular sinuses, resulting in 'marbling', and indicating hemorrhage in the drainage area. Classical swine fever. Pig.



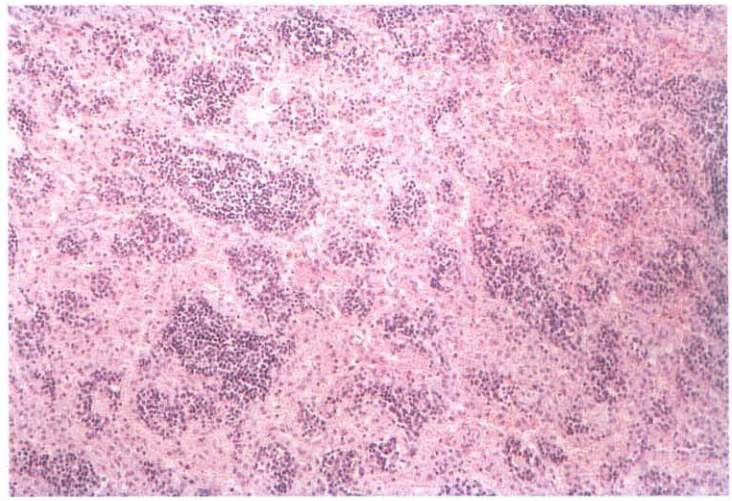

**1-13** Acute reactive hyperplasia (acute lymphadenitis)
Bronchial lymph node. Accumulation of neutrophils and activated mononuclear cells in sinuses (S). Note the inconspicuous lining of the medullary cord (M). Dog. HE.



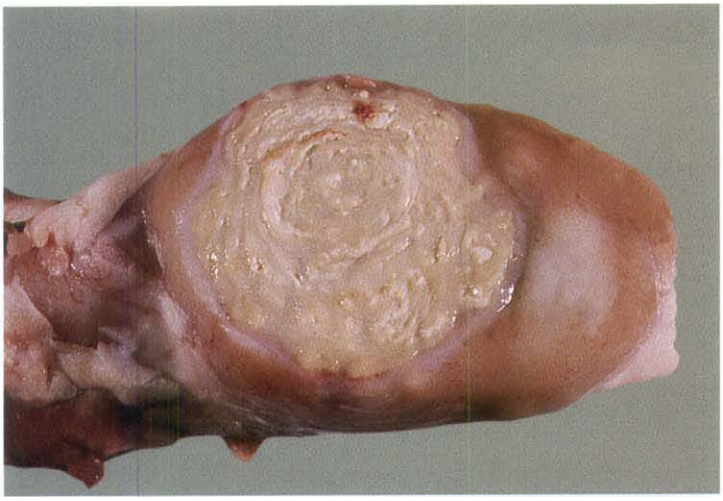
**1-14** Chronic reactive hyperplasia (chronic lymphadenitis)
Bronchial lymph node. Reactive follicular hyperplasia with marked enlargement of germinal centres (B-cell activity). Slight increase of the interfollicular lymphoid tissue (mostly T-cells). Sinuses filled with erythrocytes drained from the lung and some reticulo-endothelial hyperplasia. Enzootic pneumonia; aspiration of blood during slaughter. Pig. HE.



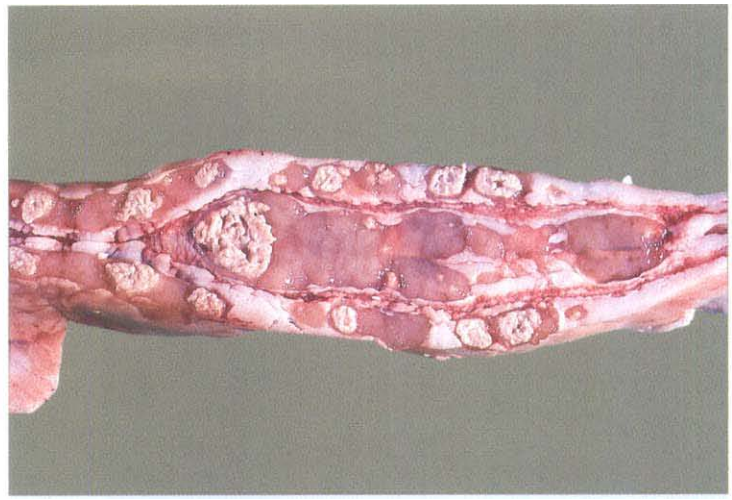
**1-15** Chronic reactive hyperplasia (chronic lymphadenitis)
Peripheral lymph node. Massive infiltration of medullary cords, mainly by plasma cells, lymphocytes and mononuclear phagocytes. Many mononuclear cells in sinuses (sinus histiocytosis), erythrophagocytosis (arrows). Experimental *Trypanosoma brucei* infection. Rabbit. HE.



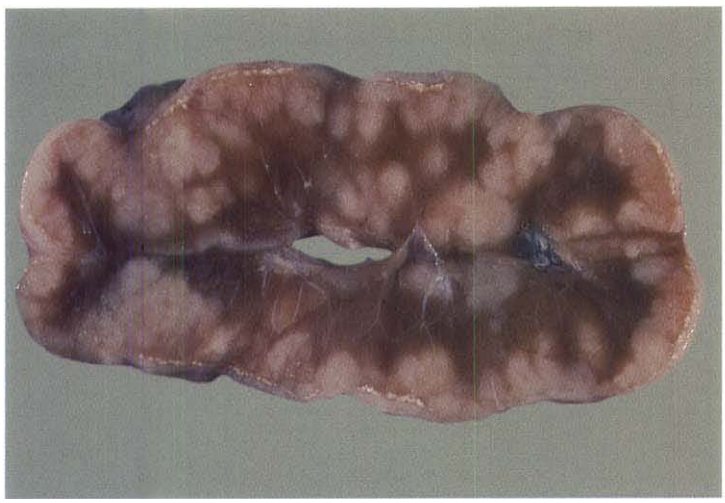
**1-16** Chronic lymphadenitis and fibrosis
Lymph node. Proliferation of reticular cells and formation of connective tissue in medullary sinuses (fibrous transformation). Atrophy of medullary cords. Cat. HE.



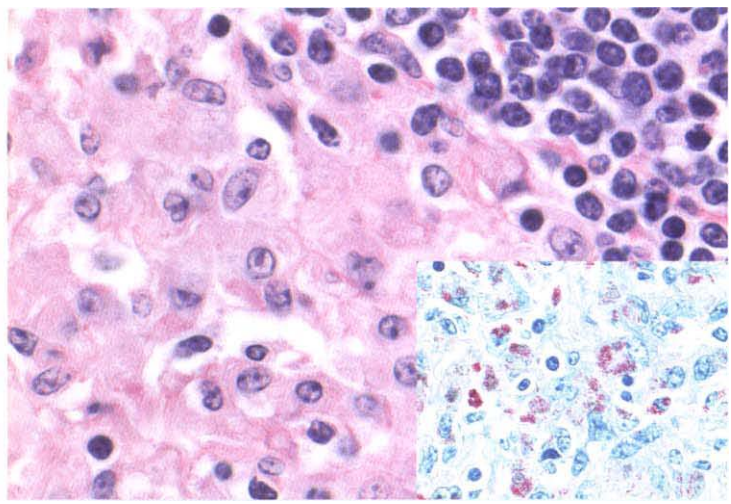
**1-17** Suppurative lymphadenitis
Superficial lymph node, cut surface. Encapsulated abscess containing concentric lamellae, inspissated pus, sometimes greenish (many eosinophils). Lamellar configuration due to repetitive necrosis of capsule, accumulation of inflammatory cells and formation of a new capsule. *Corynebacterium pseudotuberculosis* infection: caseous lymphadenitis, 'pseudotuberculosis'. Sheep.



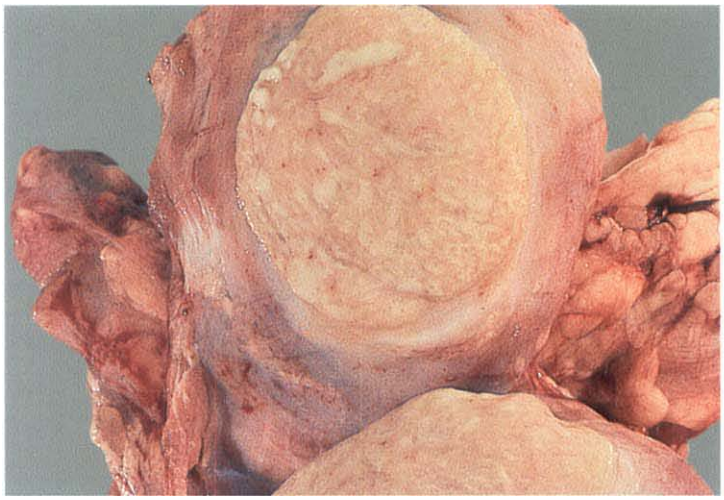
**1-18** Chronic caseous granulomatous lymphadenitis
Mesenteric lymph nodes, cut surface. Granulomas with caseous necrosis and calcification as part of incomplete primary complex. Typically, no caseation or calcification is found in avian tuberculosis of pigs, except in mesenteric lymph nodes. Avian tuberculosis (*Mycobacterium avium*). Pig.



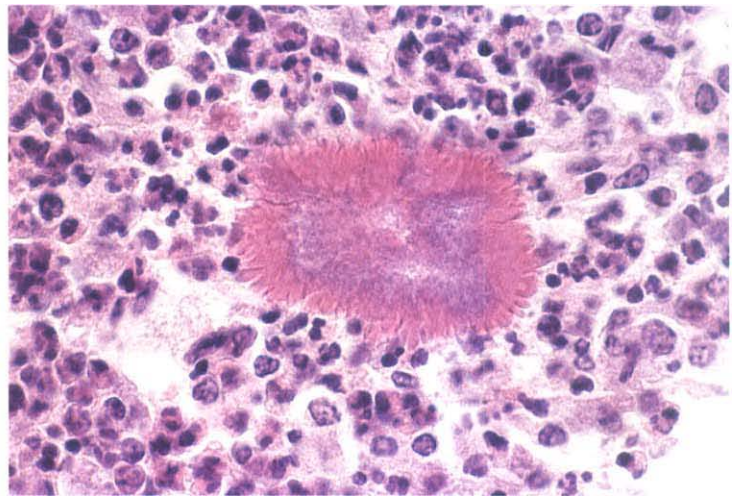
**1-19** Chronic granulomatous lymphadenitis
Mesenteric lymph node, cut surface. Enlargement of cortical region by paracortical lymphoid hyperplasia, and infiltration by epithelioid cells. Small rim of caseation just beneath capsule (no caseation occurs in cattle). Paratuberculosis (*Mycobacterium avium* subspecies *paratuberculosis*). Goat.



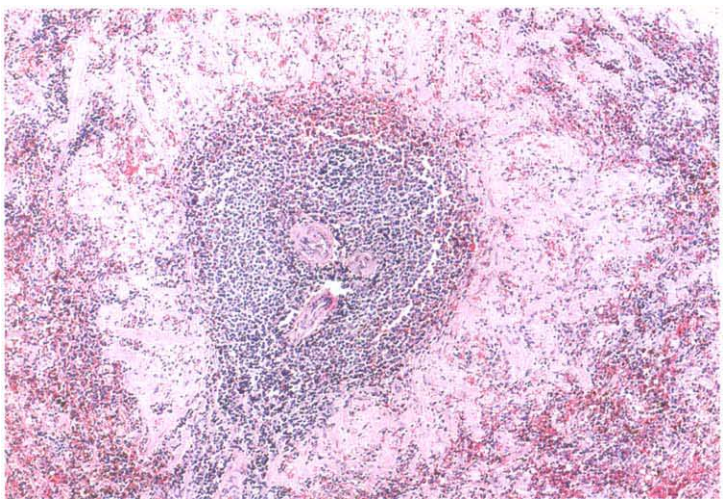
**1-20** Chronic granulomatous lymphadenitis
Mesenteric lymph node. Infiltration of groups of epithelioid cells (large macrophages, pale-staining cytoplasm) in paracortex (left). Insert: many red stained bacilli in epithelioid cells. Paratuberculosis (*Mycobacterium avium* subspecies *paratuberculosis*). Goat. HE, insert: Ziehl–Neelsen stain for acid fastness of mycobacteria.



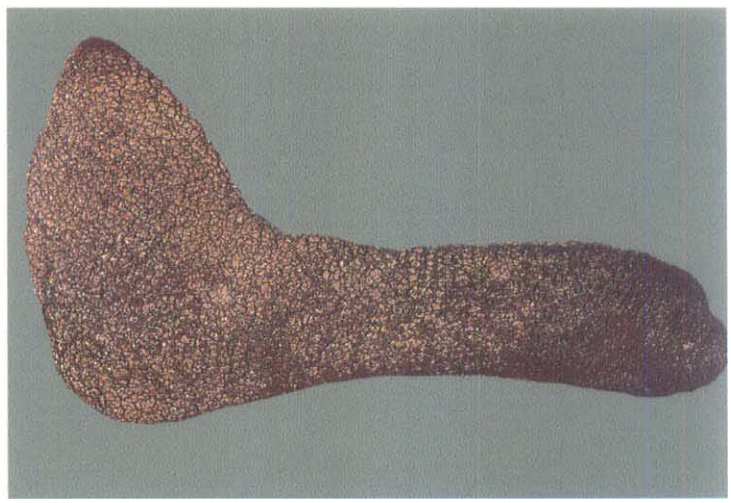
**1-21** Chronic pyogranulomatous lymphadenitis
Mandibular lymph node, cut surface. A fibrous capsule around soft, gray-yellow, bulging granulomatous tissue containing multiple small abscesses. Actinobacillosis (*Actinobacillus lignieresii*). Cow.



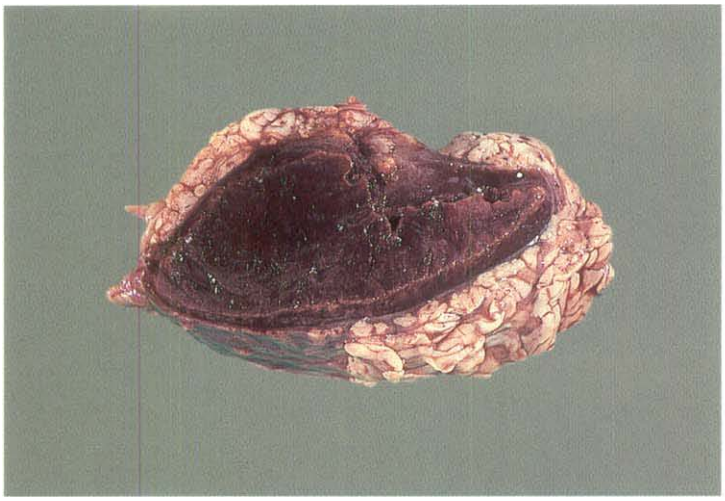
**1-22** Miliary abscess in pyogranulomatous lymphadenitis
'Sulfur granule' (blue stained colony of bacteria) with a red regular peripheral rim of eosinophilic clubs surrounded by viable and necrotic macrophages and neutrophils (pus). Actinobacillosis (*Actinobacillus lignieresii*). Cow. HE.



**1-23** Amyloid deposition
Amorphous proteinaceous substance in the red pulp cords around lymphoid follicles, resulting in a 'lardaceous' spleen. In other cases, amyloid deposition is limited to the follicles, producing a 'sago' spleen with tapioca-like granules. Amyloidosis. Pig. HE.

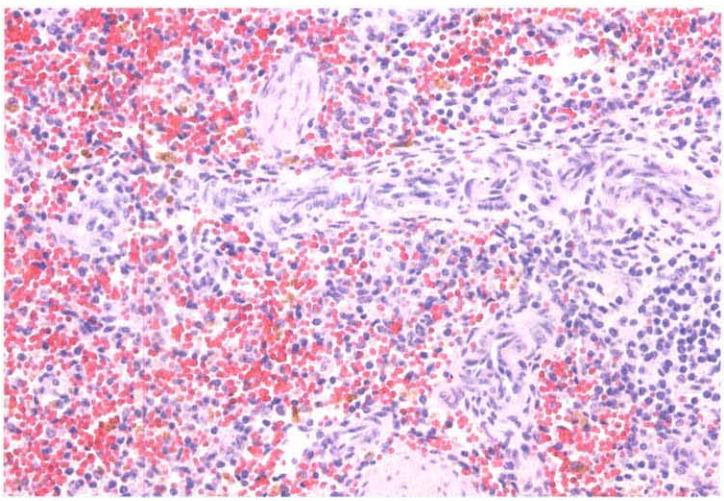


**1-24** Siderofibrosis (Gamna-Gandy nodules)
Spleen. Yellow-brown (sub)capsular nodules and plaques after organization of small infarcts, hemorrhages or herniation of red pulp. Often found next to the hilus and edges, or in scars and trabeculae. Histologically made up of fibrotic foci with macrophages and deposition of hemosiderin and iron or calcium salts on elastic fibers and in connective tissue. Dog.

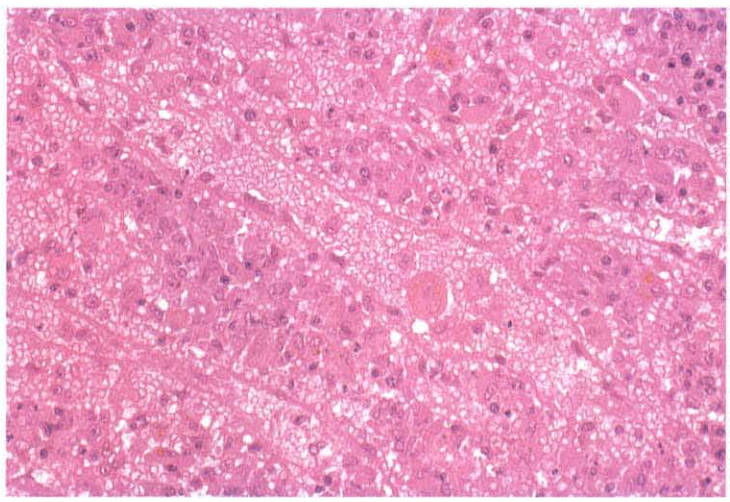


**1-25** Torsion
Spleen, transverse section. The whole spleen wrapped in the major omentum. Hemorrhagic infarction due to compression of veins. Pig.

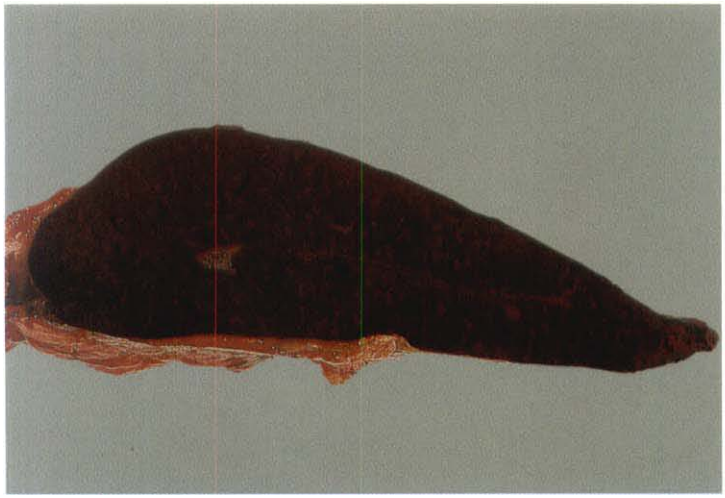
**1-26** Hemorrhagic infarcts
Spleen. Prominent, blue-red, more or less wedge-shaped, firm areas, peripherally located and surrounded by a hyperemic demarcation. Possible pathogeneses: *a* Complete arterial occlusion and influx of blood from anastomotic vessels; *b* Partial arterial occlusion and seepage of blood; *c* Venous obstruction. Thromboendocarditis by hemolytic streptococci. Dog.



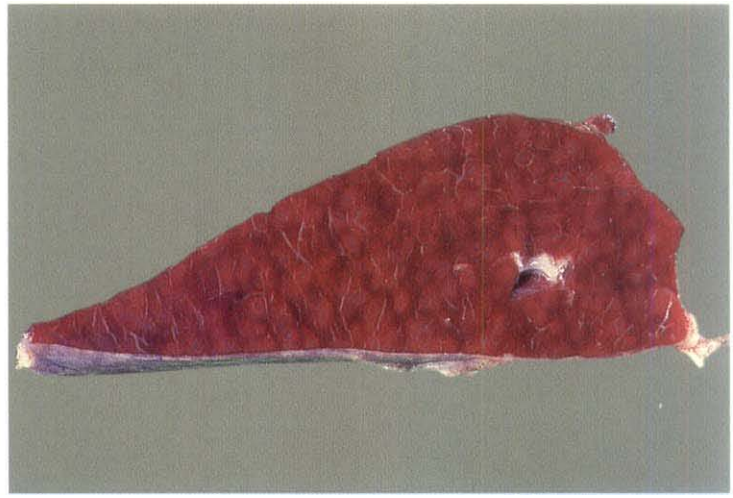
**1-27** Depletion of follicles and periarterial lymphoid sheath (PALS)
Spleen. Area of white pulp around central artery lacks normal numbers of T-lymphocytes and B-lymphocytes. Similar morphology is seen in lymphocytolysis due to excessive hypercortisolism, debilitation and acute viral infections with lymphoid cell destruction. Normal red pulp. Fell pony syndrome. Horse. HE.



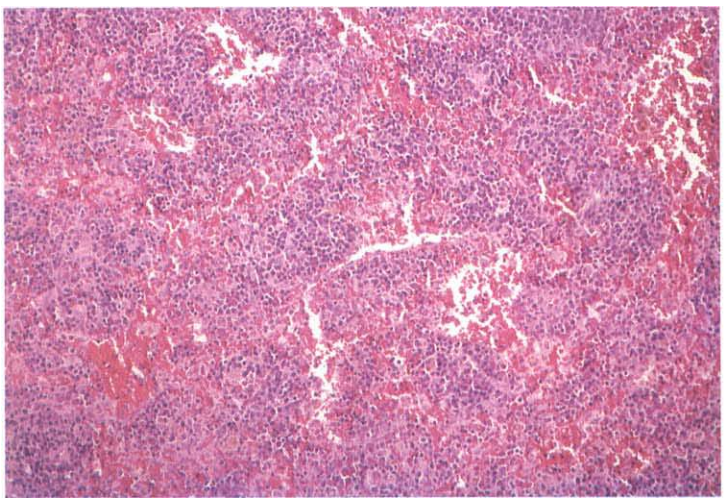
**1-28** Reactive spleen ('activated spleen')
Red pulp. Marked reticuloendothelial hyperplasia; many hemosiderin-containing macrophages in cords of Billroth. Congestion of sinuses and cords. Exaggeration of features may quickly return to normal after control of infection. Experimental *Trypanosoma brucei* infection. Rabbit. HE.



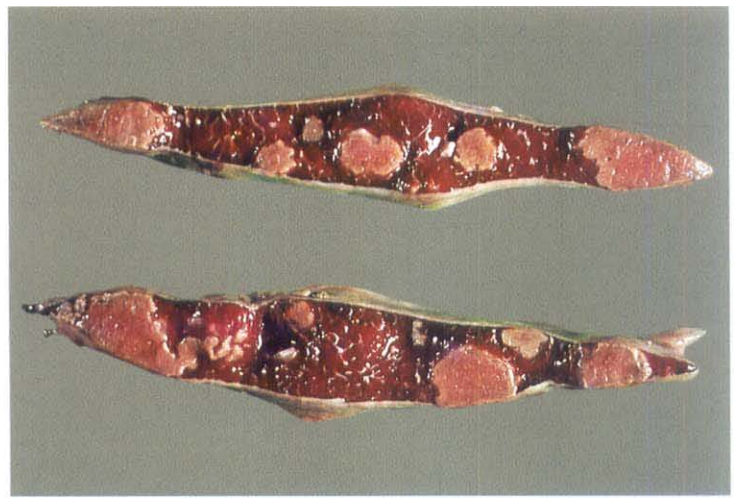
**1-29** Acute reactive hyperplasia (acute hyperemic splenitis, 'acute splenic tumor')
Spleen, transverse section. Enlargement mainly by active hyperemia. Histologically further characterized by some reticuloendothelial hypertrophy and hyperplasia, and some granulocytic infiltration. This is a common finding in peracute systemic infections (e.g. anthrax) or bacterial intoxications (e.g. *Clostridium* enterotoxemia) and in passive hyperemia, shock or barbiturate poisoning. Goat.



**1-30** Chronic reactive hyperplasia (hyperplastic splenitis)
Spleen, transverse section. Enlarged, firm and pale spleen due to marked reticuloendothelial and lymphoid hyperplasia (Malpighian corpuscles clearly visible), variable granulocyte accumulation, and many plasma cells in red pulp, possibly leading to fibrosis of red pulp. Chronic mastitis. Goat.

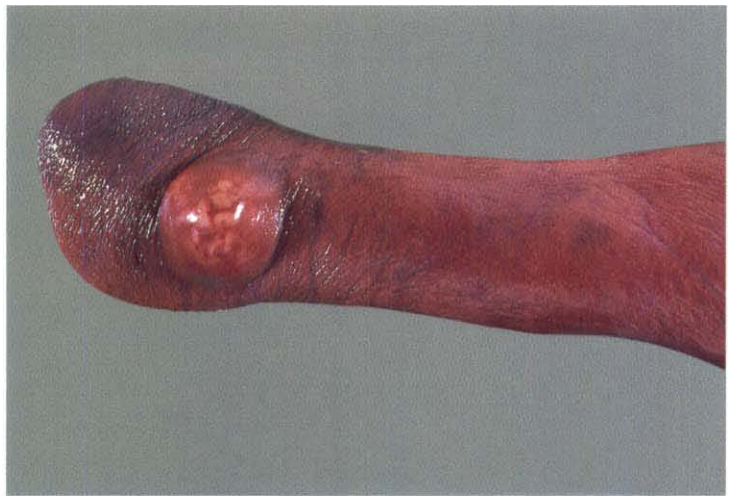


**1-31** Chronic reactive hyperplasia (hyperplastic splenitis)
Red pulp. Widened, hypercellular cords of Billroth, containing many lymphocytes and plasma cells and congested sinuses. Chronic experimental *Trypanosoma brucei* infection. Rabbit. HE.

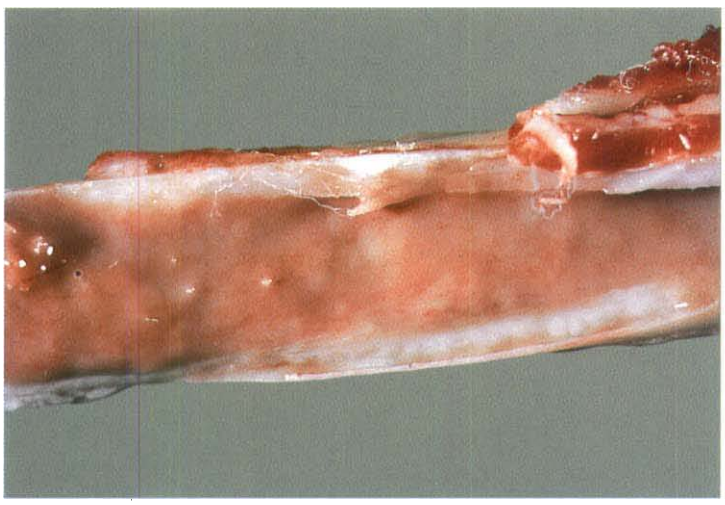


**1-32** Necrotizing splenitis, multifocal
Spleen, transverse section. Prominent, firm, yellowish, dull-surfaced foci of coagulation necrosis in random distribution in contrast to peripheral location of anemic infarcts. Infection with *Fusobacterium necrophorum* (necrobacillosis). Cow.

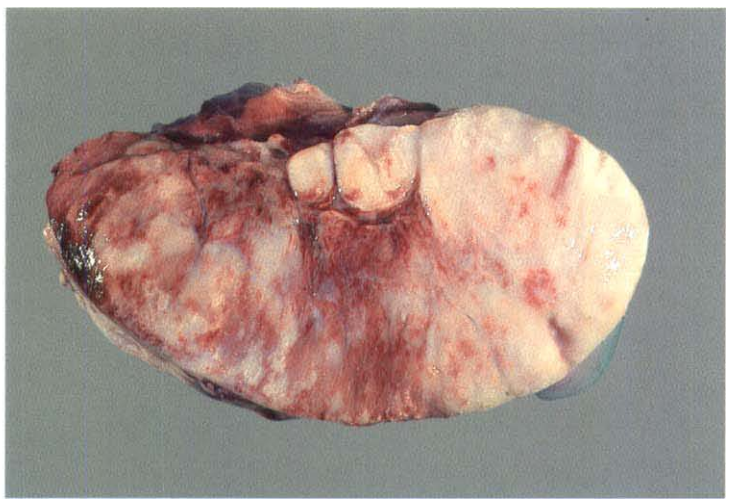
**1-33** Gangrenous splenitis
Spleen, cut surface. Liquid, gray, foul-smelling focus, resulting from putrefaction of necrotic tissue or purulent exudate caused by saprophytic bacteria (wet gangrene); generally due to perforating traumatic reticuloperitonitis. Traumatic reticuloperitonitis. Cow.



**1-34** Nodular hyperplasia
Spleen. Benign, soft nodule containing an admixture of areas of proliferated and disorganized red and white pulp, the latter seen histologically as large lymphoid aggregates without central artery. Mainly seen in older dogs.

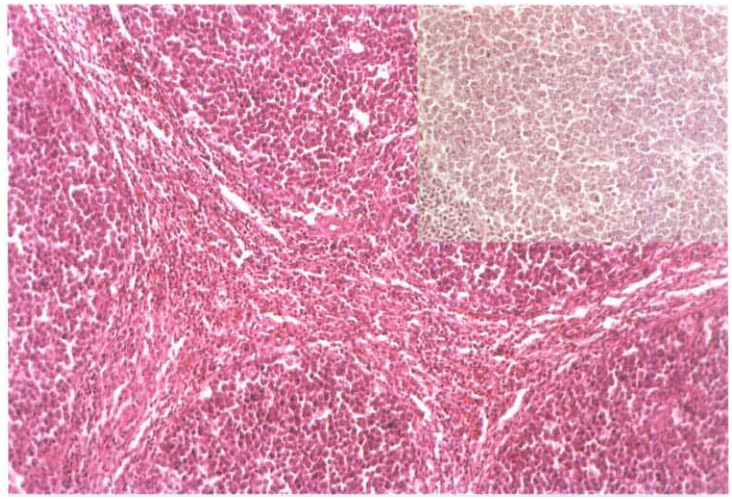


**1-35** Lymphoma (malignant lymphoma, lymphosarcoma, lymphoid leukosis)
Bone marrow, femoral diaphysis. Fatty marrow diffusely displaced by very soft, gray-pink tumorous lymphoid cells. In this case many immature lymphoid cells in peripheral circulation (lymphoid leukemia) and widespread infiltrates elsewhere; site of primary tumor unknown. Dog.

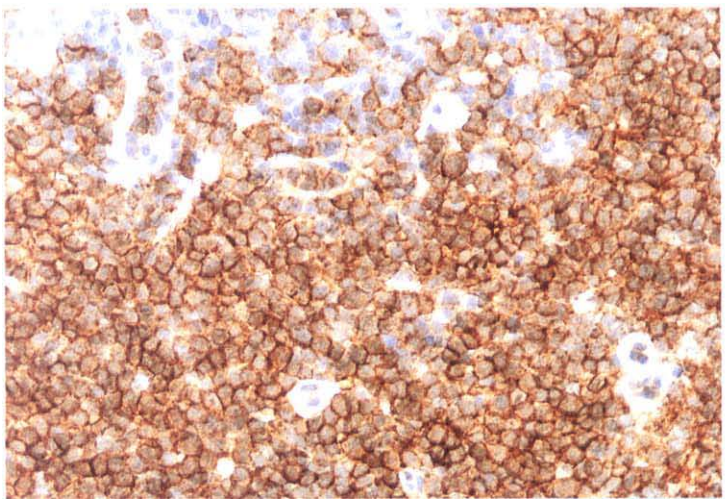


**1-36** Lymphoma (malignant lymphoma, lymphosarcoma, lymphoid leukosis)
Cervical lymph node, cut surface. Enlarged, soft, gray-white lymph node with hemorrhages. No cortex or medulla recognizable. Primary lymphoma in thymic region, metastases in regional lymph nodes and widespread dissemination (liver, spleen), no leukemia. Young cow.

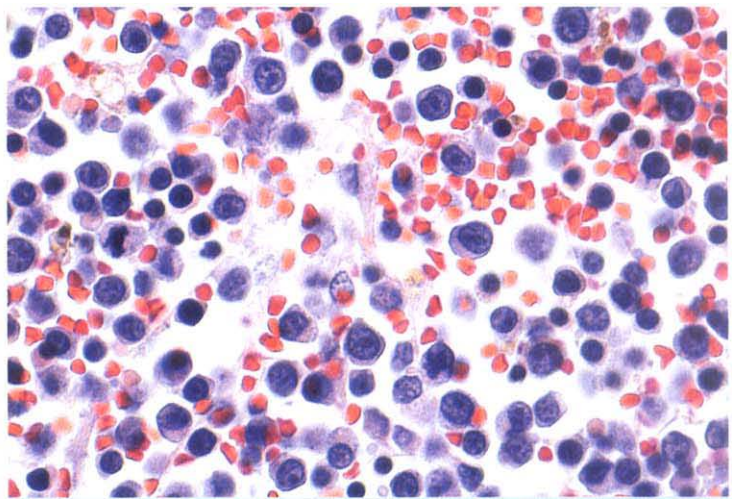
**1-37** Lymphoma (malignant lymphoma, lymphosarcoma, lymphoid leukosis)
Spleen. Extreme splenomegaly, grayish-pink with local dark red areas (hemorrhagic or less leukotic). This can occur in primary lymphoid leukemia, as well as in multicentric lymphoma. In this case neoplastic cells were present in peripheral circulation. Dog.



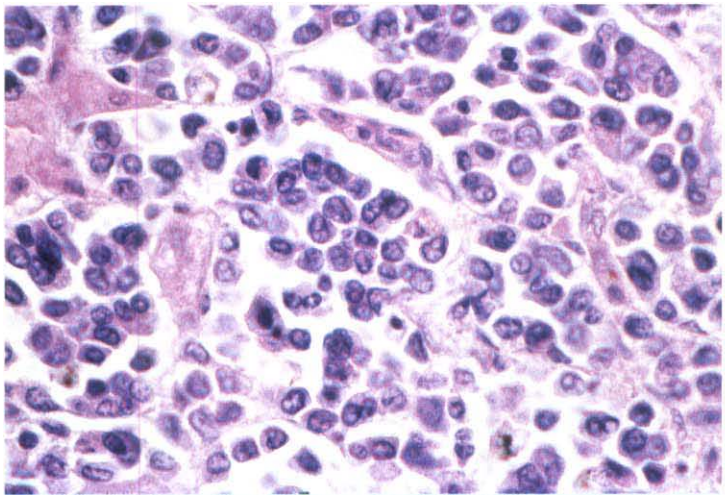
**1-38** Lymphoma (malignant lymphoma, lymphosarcoma, lymphoid leukosis)
Bursa of Fabricius. Follicles replaced by tumorous lymphoblasts. Lymphoproliferative disorder caused by RNA-virus, primarily affecting the B-cells of the bursa; later widespread dissemination. Chicken. HE. Insert: higher magnification of tumorous lymphoblasts. HE



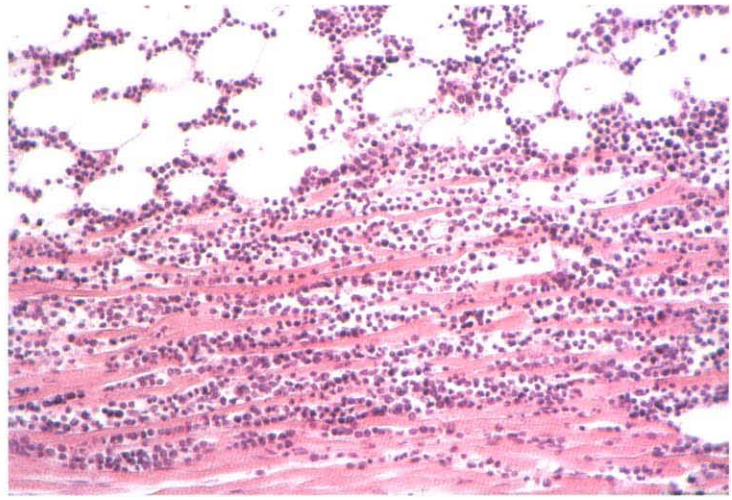
**1-39** Lymphoma (malignant lymphoma, lymphosarcoma, lymphoid leukosis)
T-cell lymphoma. Identification of tumor cell lineage by immunohistochemistry. Dog. Immunoperoxidase stain for CD3.



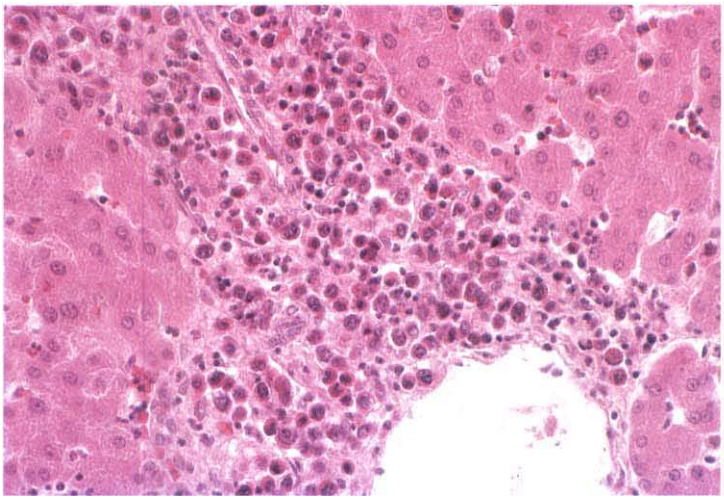
**1-40** Erythremic myelosis (erythroid leukosis)
Spleen. Tumorous population consists of large cells with large nuclei, most of them probably erythroblasts and small cells with hyperchromatic nuclei and red cytoplasm (hemoglobin synthesis), unequivocally normoblasts. Myeloproliferative disorder, erythroid predominance, with involvement of bone marrow, spleen and other organs. Cat. HE.



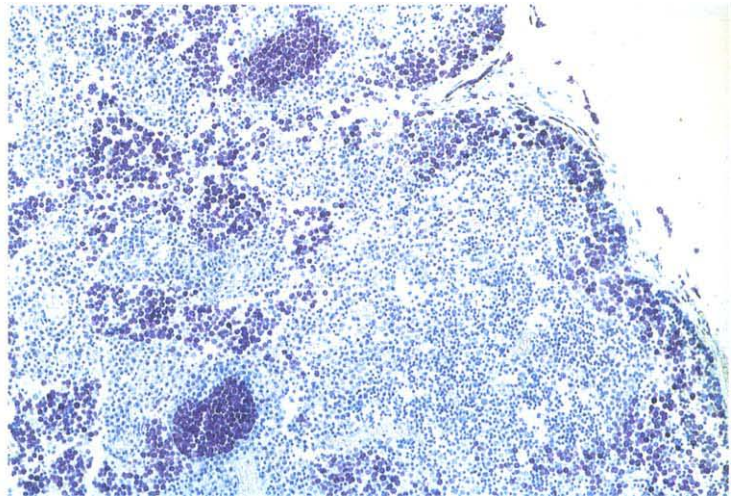
**1-41** Myeloid leukemia (myeloid leukosis)
Liver. Large tumor cells with large nuclei between hepatocytes. Note that identification of the lineage of immature blast cells only based on morphology, is often very difficult and necessitates the use of specific markers. Dog. HE.



**1-42** Myeloid leukemia (myeloid leukosis)
Myocardium and attached adipose tissue. Infiltration of numerous, mainly immature myeloid cells. Large cells with large nuclei, probably myeloblasts. Smaller cells showing distinct differentiation to mature neutrophils. Myeloproliferative disorder, myeloid predominance with involvement of bone marrow, spleen and other organs. Dog. HE.



**1-43** Myeloid leukemia (myeloid leukosis)
Liver. Portal infiltration of numerous myeloid cells, either immature, or differentiating to eosinophilic granulocytes. In many organs (e.g. bone marrow, heart, lymph nodes) formation of tumorous masses, called chloromas due to their green color. Pig. HE.



**1-44** Mast cell tumor metastasis
Peripheral lymph node. Free tumor cells in distended subcapsular and paratrabecular sinuses, showing the (ineffective) filtering of neoplastic cells. Two foci of sessile metastatic tumor cells (upper and lower border). Dissemination of primary mast cell tumor in the skin. Dog. Toluidine blue stain for metachromatic granules of mast cells.

Chapter 2

# The circulatory system



## THE CIRCULATORY SYSTEM

The circulatory system includes the heart with its pericardial sac, and the arteries, veins and lymphatic vessels.
The main lesions consist of:

- congenital abnormalities;
- hypertrophy and luminal change;
- degenerative changes;
- inflammation; and
- neoplasia.

### *Congenital abnormalities*

*Congenital abnormalities* of the heart and vessels occur in all species and can be hereditary. Developmental defects in septation of the heart, abnormal origin or abnormal persistence of arteries, and abnormalities in the cardiac valves with stenosis of the ostia are the most common findings.

### *Hypertrophy and luminal change*

*Hypertrophy* and *dilatation* of ventricles and atria are often the result of congenital abnormalities, myocardial degeneration, inflammation or valvular disease; but hypertrophy may also be induced by hyperthyroidism, chronic anemia or raised levels of erythropoietin.

#### Cardiomyopathy

If an abnormality in the myocardium underlies the cardiac dysfunction the term *cardiomyopathy* is used; often the cause is unknown, but may include inflammation, genetic abnormalities in the energy metabolism or in contractile proteins of the myocardial cells, metabolic disorders by deficiencies, or toxic dystrophies.

Cardiomyopathy occurs in three patterns:

- dilated (or congestive);
- hypertrophic; and
- restrictive.

### *Degenerative changes*

*Degenerative changes* of the heart muscle are most often due to:

- dietary deficiencies;
- intoxications;
- disturbed microcirculation (shock); and
- sepsis.

Degenerative changes of the atrioventricular valves with deposition of proteoglycans and increase of collagen are common in older dogs and may cause heart failure and, by insufficiency, atrial jet lesions. Degeneration of small vessels may cause *hemorrhages* as in porcine mulberry heart disease. A disturbed

microcirculation with *diffuse intravascular coagulation* (DIC) may also induce a *hemorrhagic diathesis*.

*Atheromatosis* and *atherosclerosis* of arteries are found, but not frequently. Marked deposition of *lipofuscin* can occur in cattle without clinical signs. Vascular and endocardial metastatic and dystrophic *calcifications* are well known. Cardiac and vascular *amyloidosis*, seen as hyalin deposits, can be part of generalized amyloidosis.

## Inflammation

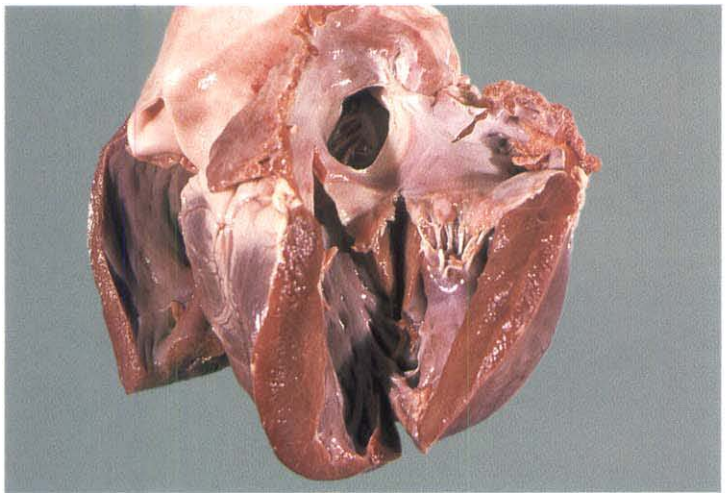
*Inflammations* are frequent disorders. Pericarditis, myocarditis, thromboendocarditis, and vasculitis are mostly caused by infectious agents (many species of bacteria, viruses, protozoa and parasites) but also immune mediated vasculitides occur. Thromboendocarditis may be followed not only by cardiac failure, but also by embolism and infarctions.

## Neoplasia

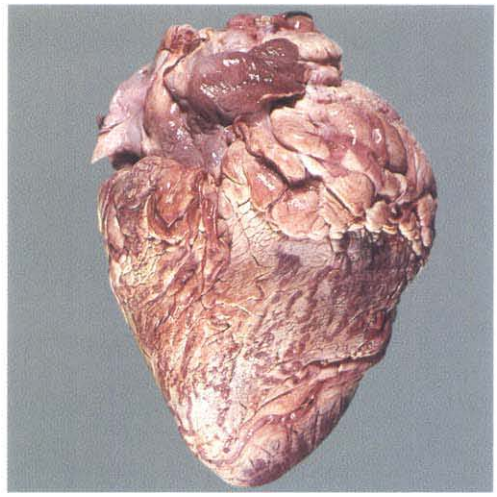
The most important *neoplasms* in the heart and pericardium include tumors of:

- the glomus aorticum (chemodectoma);
- ectopic thyroid gland tissue;
- subepicardial nerves (neurofibromas);
- endothelium of cardiac vessels and endocardium (hemangiosarcomas); and
- malignant lymphomas.

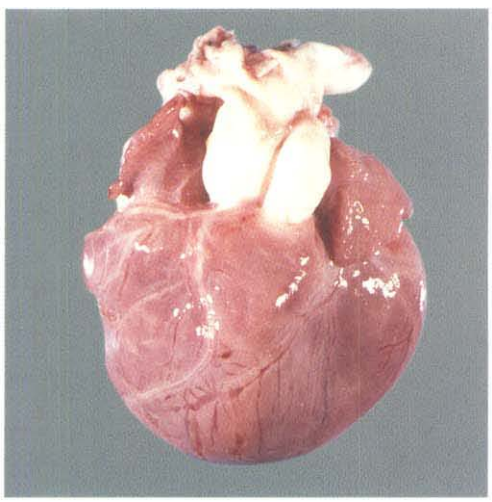
Cardiac hemangiosarcomas are most often found in shepherd and boxer dogs in the right atrium, and are the most frequent cause of sudden death due to a *hemopericardium*.



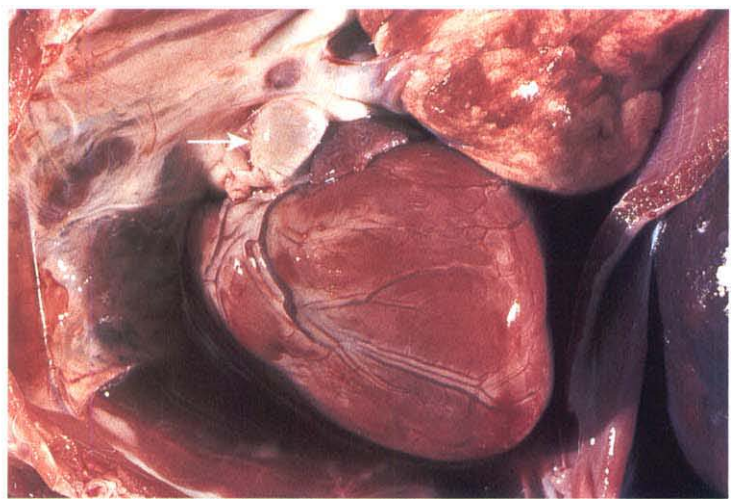
**2-1** Ostium secundum defect
A defect of the atrial septum in the region of the fossa ovalis. Pig.



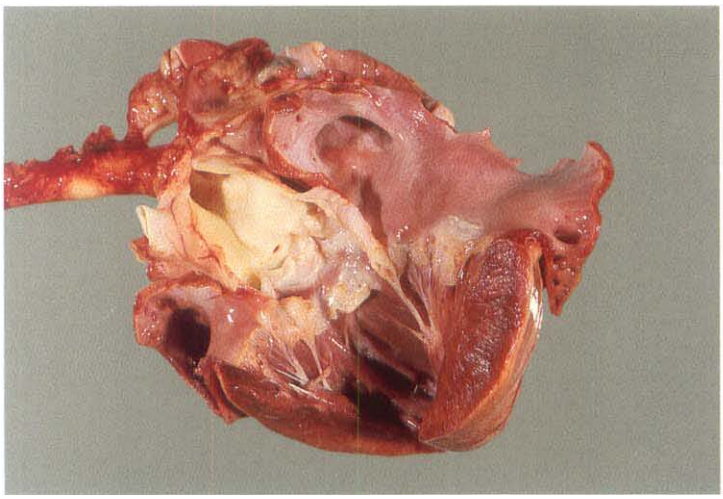
**2-2** Anomalous origin of the right coronary artery
Right coronary artery originating from the pulmonary trunk, dilated branches (subepicardial) of the left and right coronary arteries, with several anastomoses between them, in the wall of the left and right ventricle. Slaughter cow.



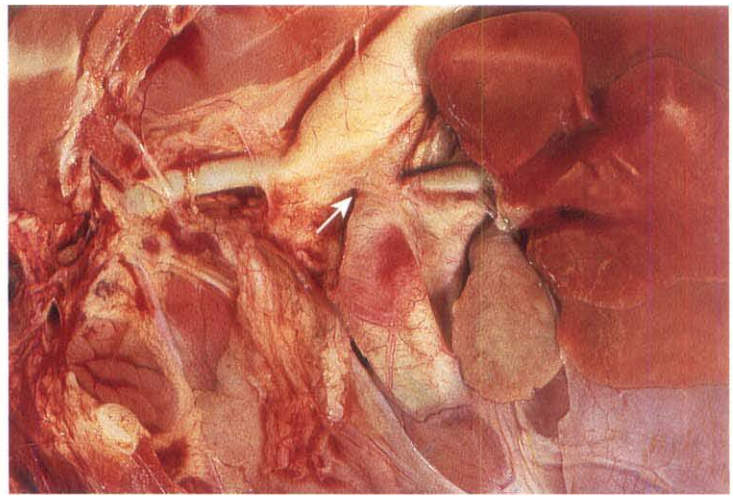
**2-3** Dextroposition of the aorta
The aorta originates from the right ventricle and is placed to the right of the pulmonic trunk. Pig, four weeks.



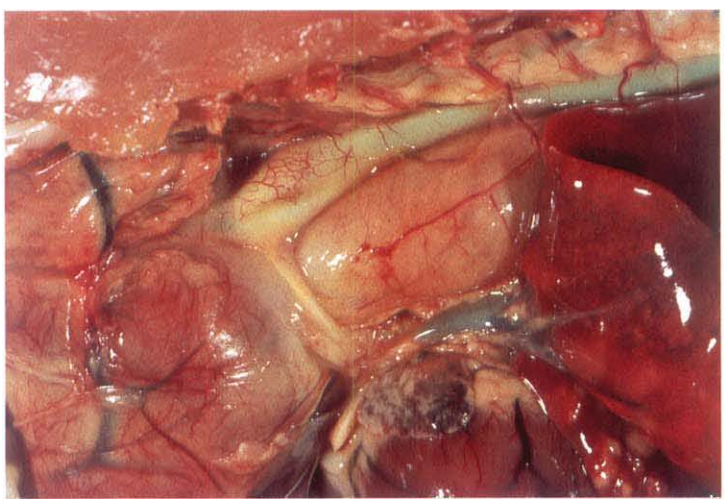
**2-4** Valvular stenosis of the pulmonary artery
Post-stenotic dilation of the pulmonary trunk (arrow) immediately distal to the valvular stenosis of the pulmonary artery. Dog, one year.



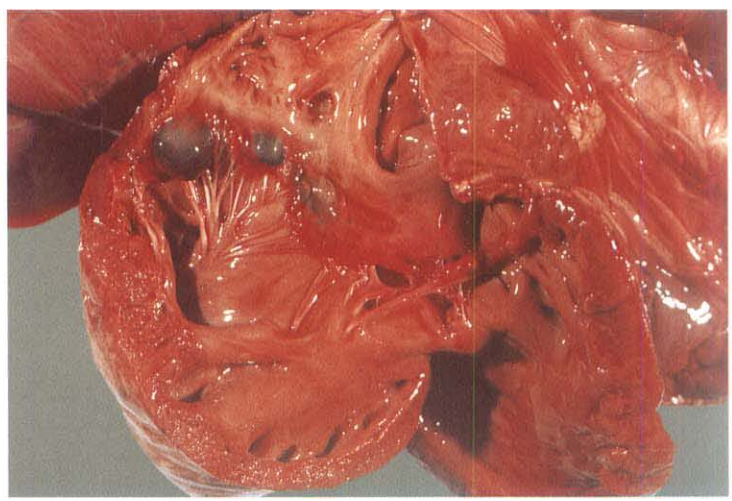
**2-5** Subvalvular aortic stenosis
Narrowing of the left ventricular outlet by a fibrous plaque directly beneath the aortic valve. Marked hypertrophy of the left ventricular wall. Dalmation dog, 8 years.



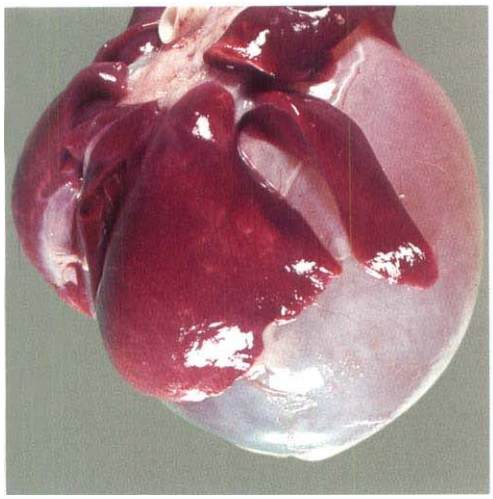
**2-6** Patent ductus arteriosus
A persistence of the shunt (arrow) between the aorta and pulmonic trunk, normally present during embryonic life. Old dog.



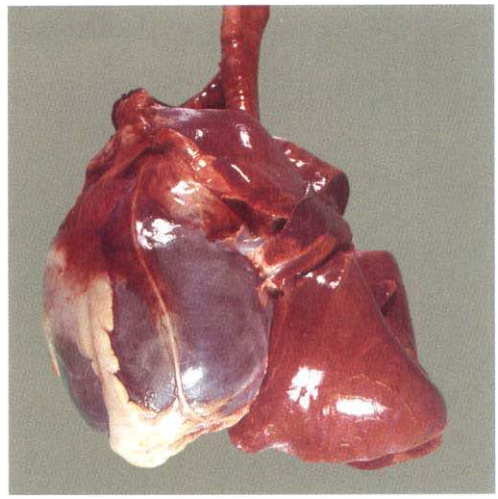
**2-7** Persistence of the right aortic arch
Vascular ring, formed by the right aortic arch, the left ligamentum arteriosum and the base of the heart. This structure encircles the esophagus and causes a stenosis of the esophagus. Prominent dilation of the esophagus anterior to the stenosis. Cat, 6 months.



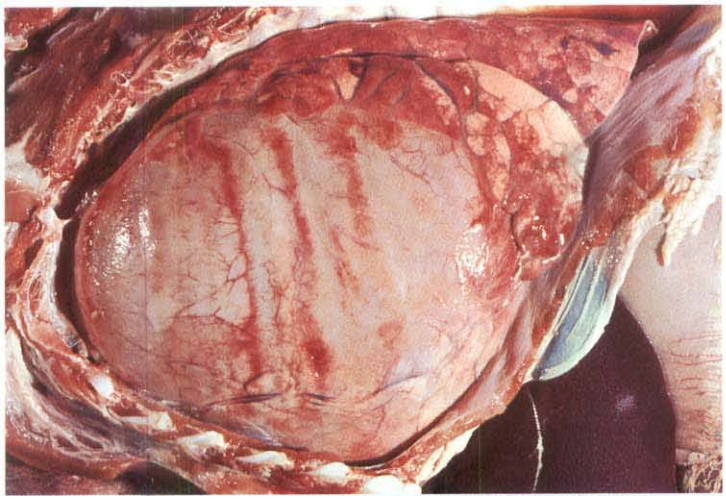
**2-8** Congenital valvular cysts
Endothelium-lined cysts filled with blood in the right atrioventricular valve. Can be found in all cardiac valves, and may also be yellow (filled with serum). Still-born calf.



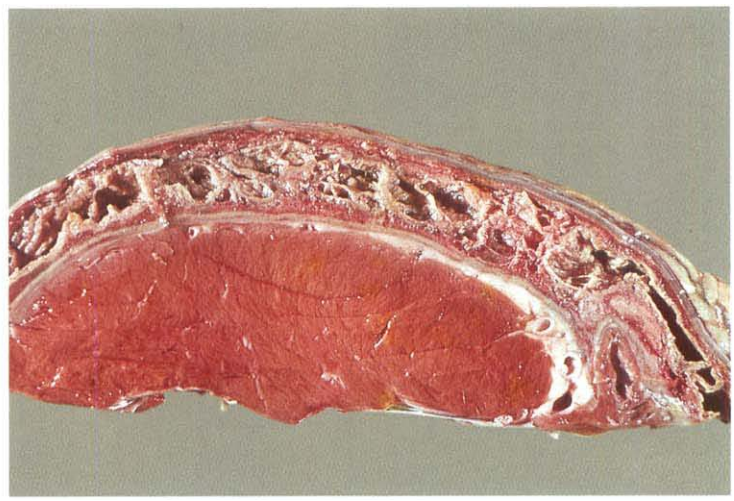
**2-9** Hydropericardium
The pericardial sac is overfilled with clear fluid; the pericardium is smooth and glistening. Myocarditis. Cat.



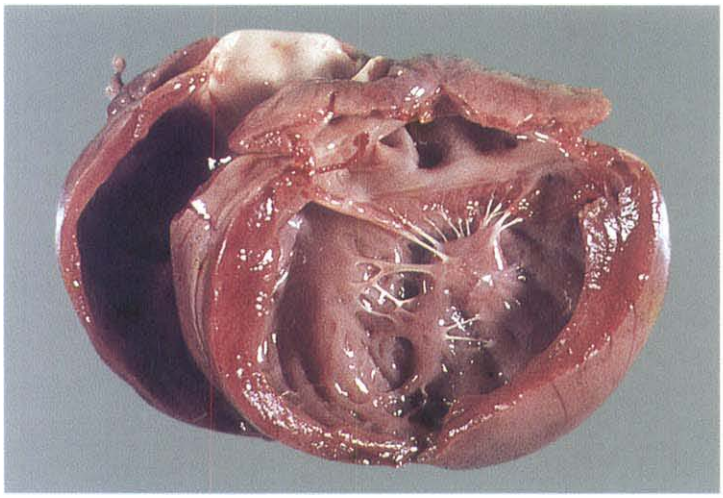
**2-10** Hemopericardium
The pericardial sac is filled with pure blood, as a result of a rupture of the right atrium, due to an infarct. Dog.



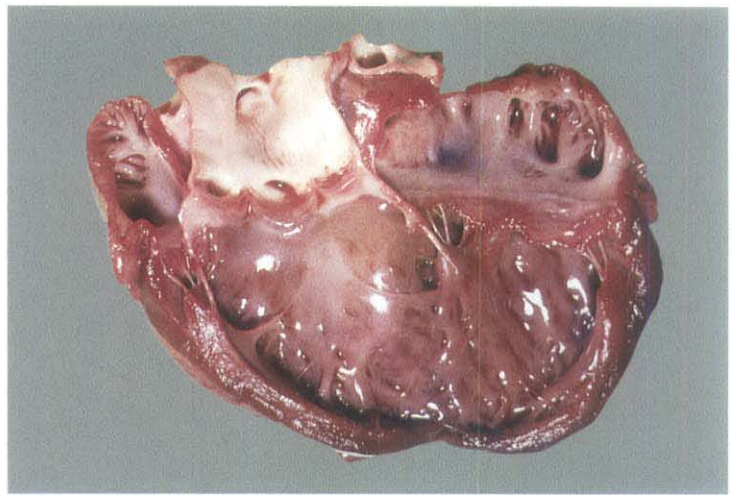
**2-11** Pericarditis
The pericardial sac is greatly enlarged due to accumulation of serofibrinous exudate. The pericardium itself is thickened and opaque. Pig.



**2-12** Chronic fibrinous pericarditis
Pericardium and left ventricular wall, cut surface. On the epi- and pericardium a thin layer of granulation tissue is visible. Between the epi- and pericardium fibrinous exudate is present. Cow.

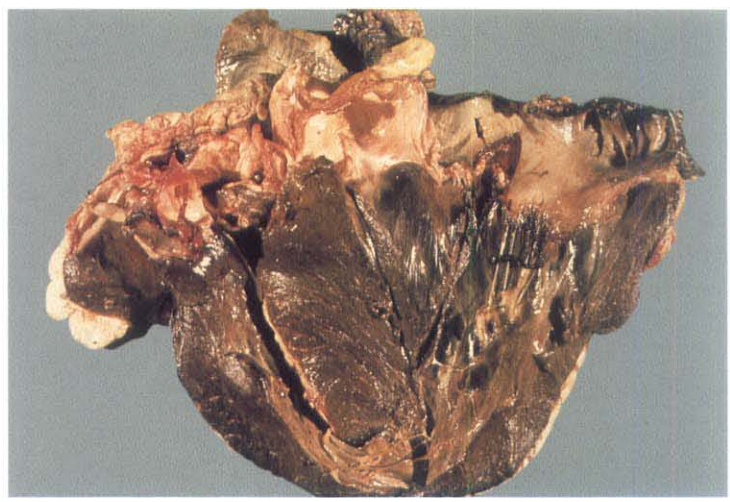


**2-13** Eccentric hypertrophy of the heart
Thickening of the left atrial and ventricular wall accompanied by dilation of the lumen. Dog.

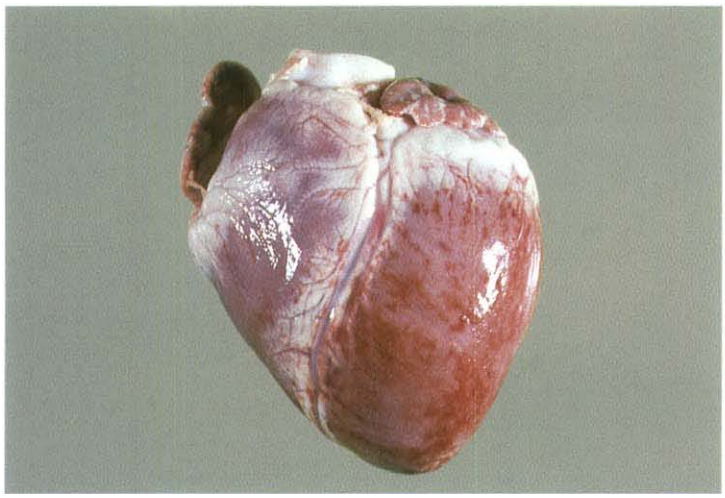


**2-14** Dilation of the heart
Dilation of the lumen and thinning of the wall of the left ventricle. The papillary muscles are attenuated. Dog.

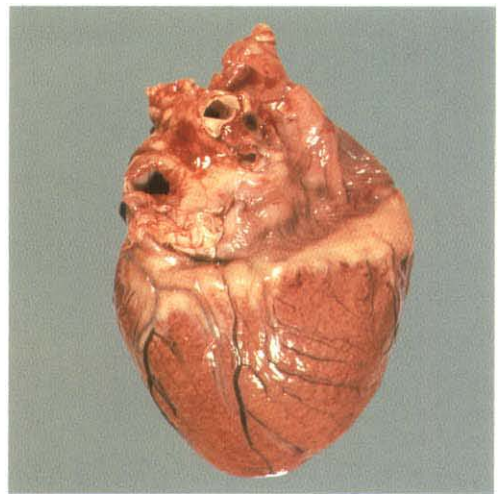
**2-15** Hypertrophic cardiomyopathy
Left and right ventricle, cross section, formalin fixed. Idiopathic concentric hypertrophy of the left ventricular wall. The hypertrophy of the ventricular septum may result in a narrowing of the aortic outflow, thus causing a muscular subaortic stenosis. European domestic shorthair cat, 12 years.



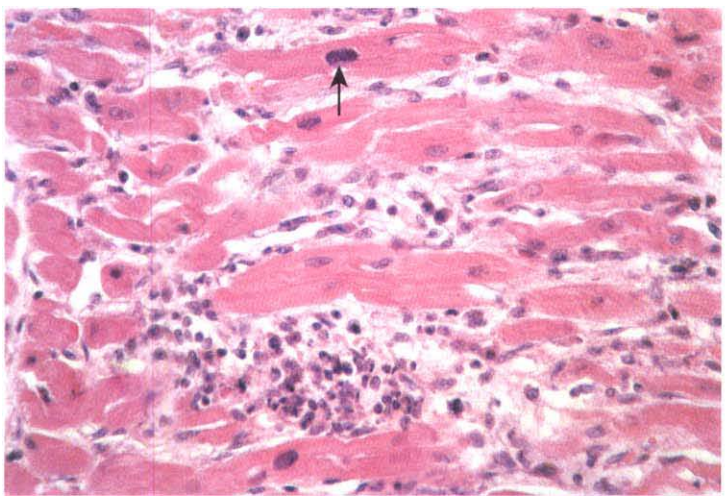
**2-16** 'Brown atrophy' of the heart
A dark pigmentation of the myocardium caused by lipofuscin deposition in the cardiomyocytes. Slaughter cow.



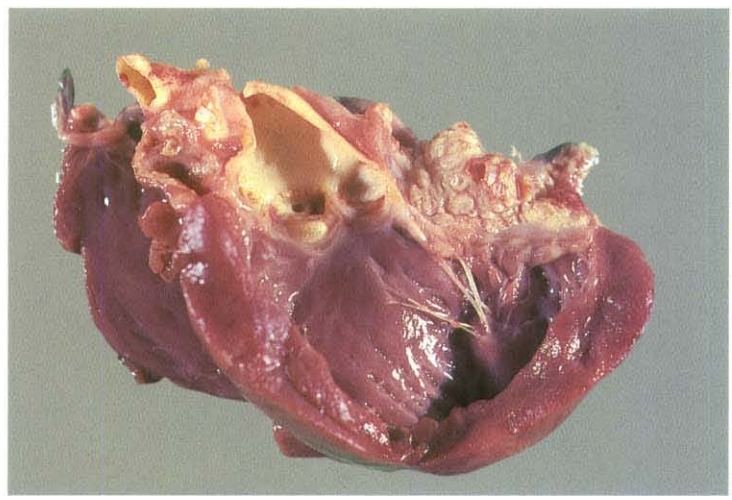
**2-17** Mulberry heart disease (microangiopathy)
Subepicardial hemorrhages and myocardial degeneration due to fibrinoid necrosis of small blood vessels. Young pig.



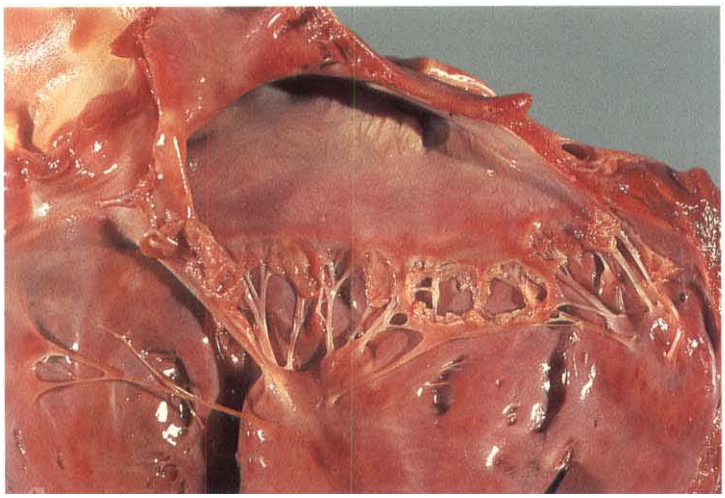
**2-18** Myocarditis
A diffuse spotty inflammation of the left and right ventricular wall. Unknown cause. Dog.



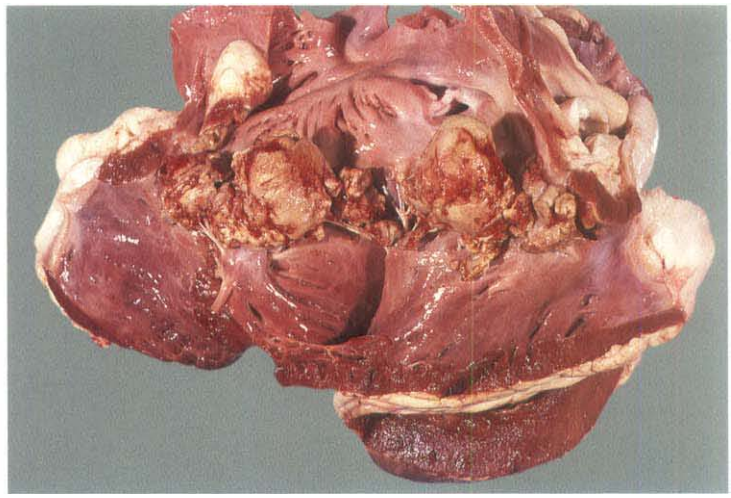
**2-19** Myocarditis
Interstitial myocarditis characterized by an infiltration of mononuclear cells and neutrophils. In the nucleus of some muscular fibers a basophilic inclusion body is present (arrow). Parvovirus infection. Pup. HE.



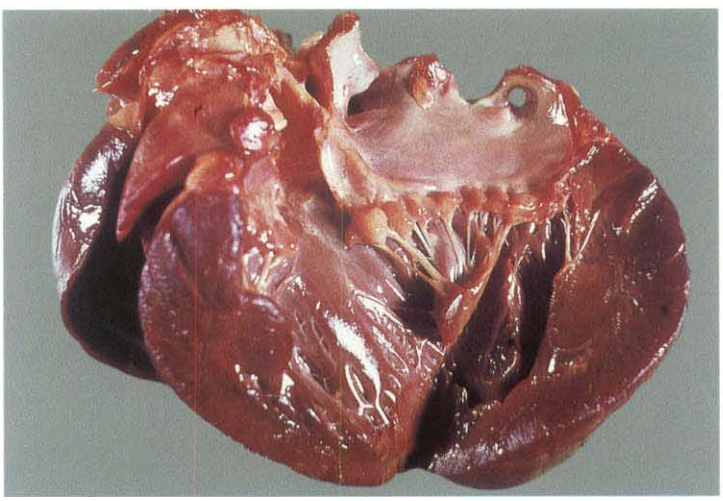
**2-20** Mural endocarditis
A necrotizing inflammation in the left atrium and in the aorta just above the semilunar valve. Uremia due to chronic renal insufficiency. Dog.



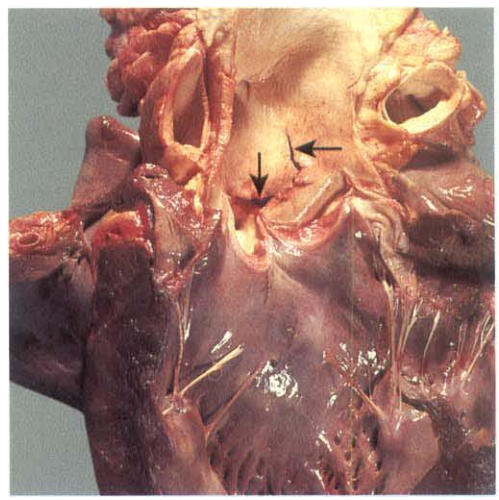
**2-21** Ulcerative valvular endocarditis
Large defects in the left atrioventricular valve due to an ulcerative inflammation of the valve. Dog.



**2-22** Valvular thromboendocarditis
Abundant deposition of fibrin on the inflamed right atrioventricular valve, due to *Arcanobacterium pyogenes* infection. Hypertrophy of the right atrium. Cow.

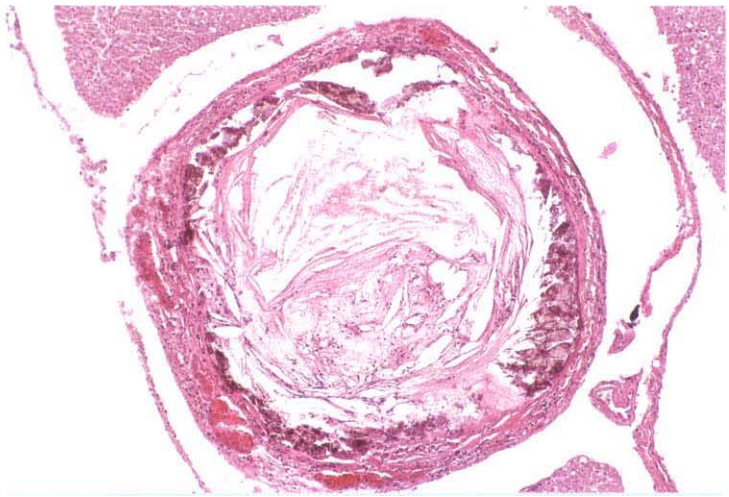


**2-23** Endocardiosis
Shortened left atrioventricular valve with nodular thickenings, predominantly at the free margin. The surface of the valve is smooth, but the valve itself is opaque and white. Dog.

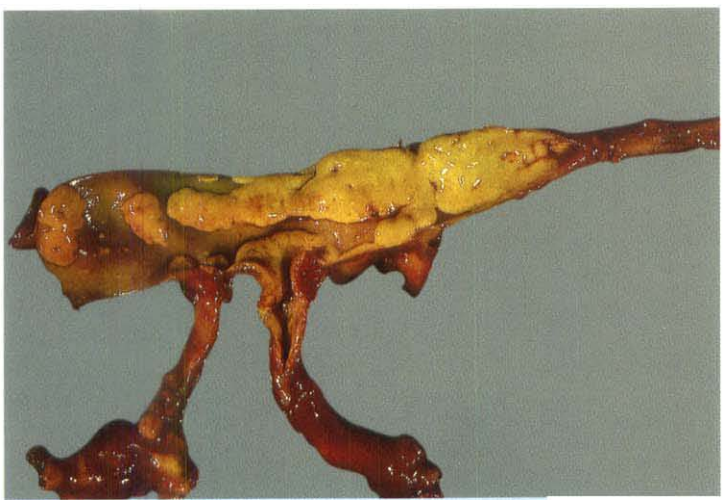


**2-24** Rupture of the aorta
Rectangular rupture (arrows) of the intrapericardial portion of the aorta, causing a hemopericardium. No predisposing lesion was present in the aortic wall. Horse.

**2-25** Amyloid deposition
Intramural artery of the heart. Homogeneous, pink thickening of the vessel wall with narrowing of the lumen. Deposition of amyloid in intima and media, except for a thin interrupted rim at the periphery. Dog, 10 years. HE.



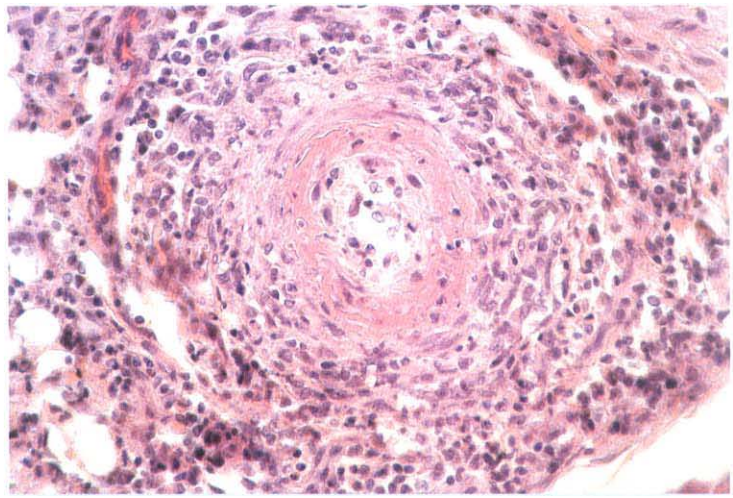
**2-26** Atherosclerosis
Meningeal artery. Severe involvement of the intima and media. Atheromatous lesion (atheroma) composed of lipid material with typical cholesterol clefts, foam cells, cellular debris and fibrous tissue. Massive calcification is evident. Hypothyroidism due to lymphocytic thyroiditis. Dog. HE.



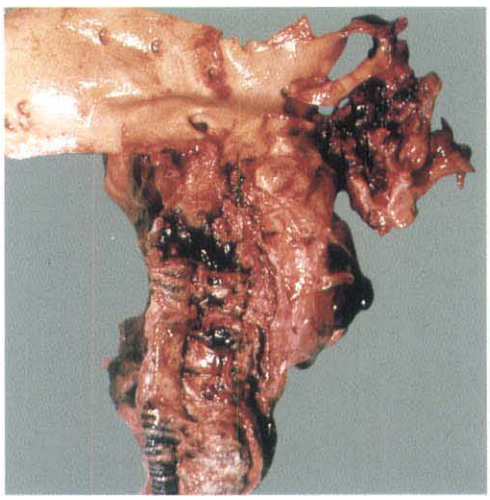
**2-27** Atheromatosis
Abdominal aorta and arteries. Yellow atheromatous plaques protruding into the lumen. Hyperlipemia. Cat.

**2-28** Calcinosis
Metastatic calcification, possibly due to enzootic calcinosis in the pulmonary artery. Slaughter cow.

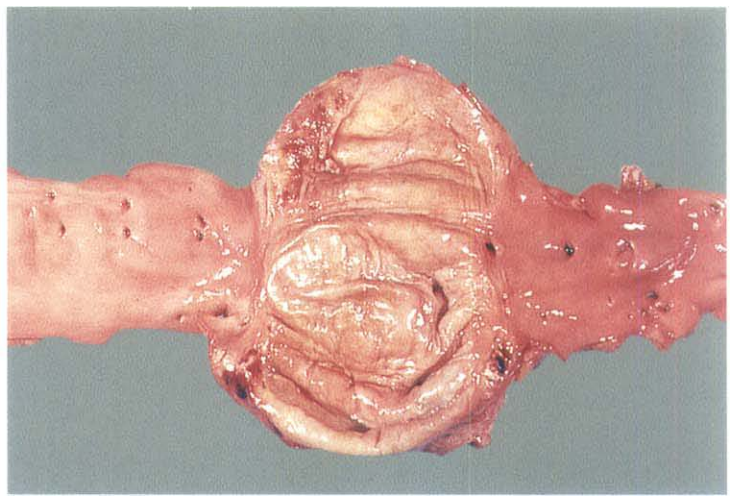
**2-29** Periarteritis nodosa
Yellow-white nodular thickening of subepicardial branches of coronary arteries. Dog.



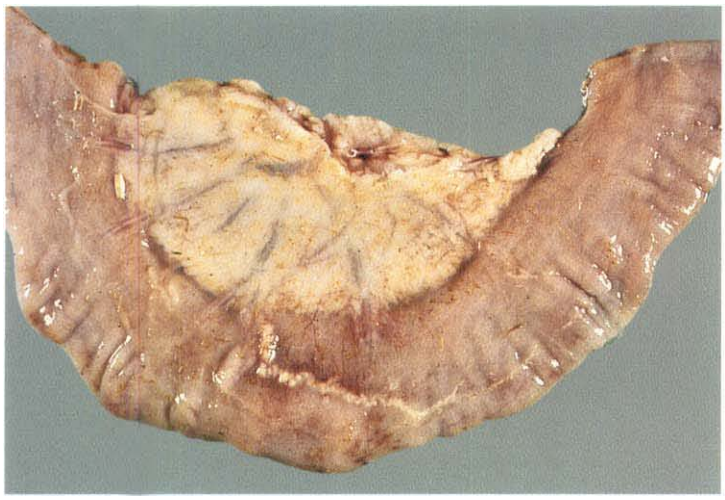
**2-30** Periarteritis nodosa
Fibrinoid necrosis of the media of an artery. Infiltration of neutrophils and mononuclear cells predominantly in the adventitia. Dog. HE.



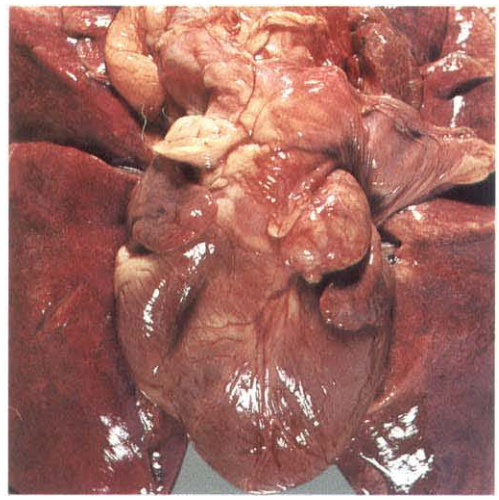
**2-31** Verminous arteritis
Abdominal aorta and cranial mesenteric artery. Verminous thromboarteritis in the root of the cranial mesenteric artery caused by larvae of *Strongylus vulgaris*. Horse.



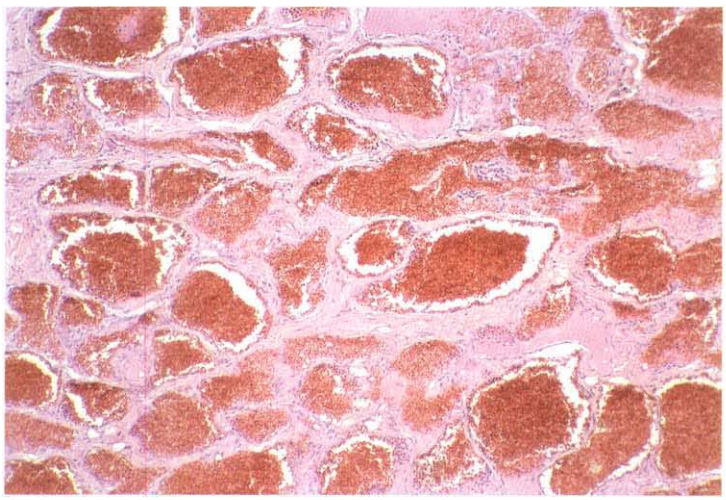
**2-32** Verminous aneurysm
Saccular aneurysm of the thoracic aorta resulting from weakening of the arterial wall due to *Strongylus vulgaris* infection. Horse.



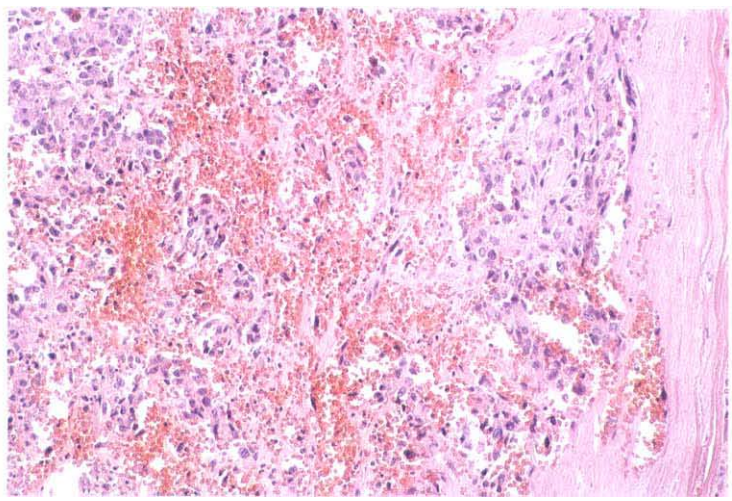
**2-33** Lymphangitis
Granulomatous lymphangitis in the wall of the small intestine. Paratuberculosis (*Mycobacterium avium* subspecies *paratuberculosis*). Cow.



**2-34** 'Heart base' tumor
Tumor at the base of the heart, localized near the pulmonic trunk. These tumors can originate from receptor cells of the aortic body or from ectopic thyroid follicular cells. This case is a chemodectoma. Dog.



**2-35** Hemangioma
Skin. A mass of thin-walled blood vessels filled with blood and separated by collagenous stroma. Dog. HE.



**2-36** Hemangiosarcoma
Myocardium. Immature endothelial cells, forming vascular spaces filled with blood among connective tissue stroma. Infiltrative growth (right). Dog. HE.

Chapter 3

# The respiratory system



## THE RESPIRATORY SYSTEM

The respiratory system can be divided into the air-conducting system and the respiratory or gas exchange area.

### *The air-conducting system*

The air-conducting system includes the nasal cavity with nasal sinuses, nasopharynx (and guttural pouch), larynx, trachea, and bronchi. Bone or cartilage provide supportive frameworks that prevent collapse of these structures. They are lined by pseudostratified ciliated epithelium with goblet cells and contain serous and mucous glands in decreasing quantities from the upper to the lower airways.

The smallest air-conducting structures, the bronchioles and alveolar ducts, are prevented from collapsing by radial traction from the surrounding alveolar structures. They are lined by a single layer of epithelium with ciliated cells and Clara cells.

### *The respiratory or gas exchange area*

The respiratory or gas exchange area consists of numerous alveoli. These are air-containing sacs formed by the alveolar septa. The latter consist of alveolar capillaries and a minimal quantity of interstitial stromal elements, and are lined by membranous pneumocytes type I and cuboidal pneumocytes type II. The latter produce and release surfactant and are also precursors of the type I cells.

### *The reaction pattern of the respiratory system*

The reaction pattern of the respiratory system can accordingly be divided into the reaction pattern of:

- the air-conducting system; and
- the respiratory area.

### The air-conducting system

The reaction pattern of cell injury, inflammation and repair is similar throughout the air-conducting system and may affect the epithelium and the surrounding structures.

*Acute injury* to the epithelium may result in shedding of the cilia, swelling and exfoliation of ciliated and goblet cells, formation of syncytial epithelial giant cells and necrosis of the epithelium.

*Chronic injury* in the larger airways may result in increased numbers of goblet cells and, in prolonged cases, squamous metaplasia of the epithelium; in the bronchioles chronic injury will result in hyperplasia of the epithelium and goblet cell metaplasia and rarely squamous metaplasia.

Usually, injury of the epithelium will be associated with an inflammatory reaction in the surrounding stromal tissue with increased permeability of the capillaries, extravasation of neutrophils (sometimes eosinophils) and macrophages, and in more prolonged cases infiltration and proliferation of lymphocytes and plasma cells and fibrosis.

The concomitant exudate in the lumen of the airways will vary according to the induced permeability of the capillaries (plasma fluid with or without larger proteins like fibrinogen) and the type and quantity of the inflammatory cells. It can be classified grossly as:

- serous (watery);
- catarrhal (watery, slightly turbid);
- mucopurulent (glistening yellow, turbid); and
- fibrinous or fibrinous-necrotic (membranous, dull).

### The respiratory area

The reaction pattern of the respiratory area can be divided into:

- circulatory disturbances including pulmonary edema;
- atelectasis and emphysema;
- pneumonia; and
- neoplasia.

#### *Circulatory disturbances and pulmonary edema*

*Pulmonary edema* may be the result of increased hydrostatic pressure, particularly seen in passive congestion, or decreased osmotic pressure of the blood, or may be due to an increased plasma leakage into the alveoli due to injury of the alveolar capillary endothelium and/or the alveolar pneumocytes type I.

Edema due to increased permeability occurs in a wide spectrum of aerogenous and hematogenous injuries, but it also forms an integral part of the inflammatory response of the respiratory area (*vide infra*).

#### *Atelectasis and emphysema*

*Atelectasis* is defined as incomplete distention of the alveoli after birth (congenital atelectasis) or collapse of the alveoli due to complete obstruction of the afferent bronchus/bronchiole with absorption of the retained air (*obstruction atelectasis*) or due to compression of the alveoli (*compression atelectasis*) due to space occupying processes in the lungs or the thoracic cavity (e.g. hydrothorax, thymic malignant lymphoma).

*Emphysema* is defined as abnormal distention of the alveoli (alveolar emphysema) and in veterinary medicine always results from partial obstruction of the airways and subsequent air-trapping in the distal alveoli.

In *chronic emphysema* alveolar walls may become atrophic and rupture and the affected lung may lose its elasticity.

*Interstitial emphysema* occurs mainly and frequently in cattle when air breaks from the alveoli into the connective tissue of the interlobular and subpleural connective tissue.

#### *Pneumonia*

*Pneumonias* can best be classified according to distribution and the gross and histological appearance of the affected lung tissue as this often allows the prediction of the likely route of entry of the agent and possible etiology.

*Lobar* or *lobular* distributed *pneumonias*, usually with cranioventral consolidation, are aerogenous infections and are often associated with bronchitis. The classification of these lobar or lobular pneumonias according to the gross and histological appearance of the affected lung tissue is based on the type of exudate:

- The exudates may grossly be fluid (*catarrhal pneumonia*) and consist of edema and neutrophils/macrophages.
- Complications in catarrhal pneumonia are severe focal or diffuse accumulations of neutrophils with secondary suppurative necrosis of the lung tissue resulting in focal abscessation or in diffuse *suppurative* (or *purulent*) pneumonia.
- The exudates may be more solid due to the simultaneous presence of fibrin (*fibrinous pneumonia*) associated with severe vascular injury with leakage of fibrinogen (and erythrocytes) into the alveoli.
- Fibrinous pneumonia is often complicated by coagulative necrosis of lung tissue (*fibrinous-necrotizing pneumonia*) with subsequent demarcation and, when the animal survives, encapsulation.

*Diffuse pneumonias* can be aerogenous or hematogenous in origin, affect primarily the interstitium, and can be classified according to the type of exudate in acute or chronic interstitial pneumonias:

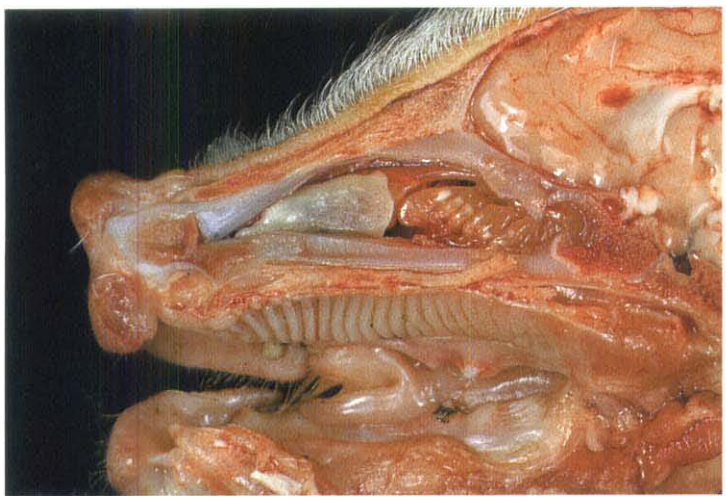
- In *acute serous interstitial pneumonia* the initial event is a marked capillary permeability with leakage of proteinaceous fluid into the alveoli, and destruction/loss of alveolar pneumocytes type I. Inspissation of the proteinaceous material in both alveoli and bronchioles may result in the formation of hyaline membranes; to replace the lost type I cells proliferation of cubic pneumocytes type II will occur within some days causing epithelization of the alveolar septa. Inflammatory cells are usually scant or absent.
- *Acute fibrinous-necrotizing interstitial pneumonias* usually are the result of viral or protozoal hematogenic infections causing fibrinoid necrosis of the alveolar septa and severe exudation of proteinaceous/fibrinous material into the alveoli often associated with a slight to moderate number of inflammatory cells.

- *Chronic interstitial pneumonia* may result from persistent alveolar interstitial injury due to Arthus type allergic reactions as in 'farmer's lung' in man and cattle, or may be primarily proliferative as a result of a persistent viral infection like Maedi in sheep.

*Multifocal pneumonias* may be hematogenous (embolic or *metastatic pneumonia*) or aerogenous in origin; the type of lesion depends on the organism present and may be purulent (abscesses), necrotizing or necropurulent, or granulomatous.

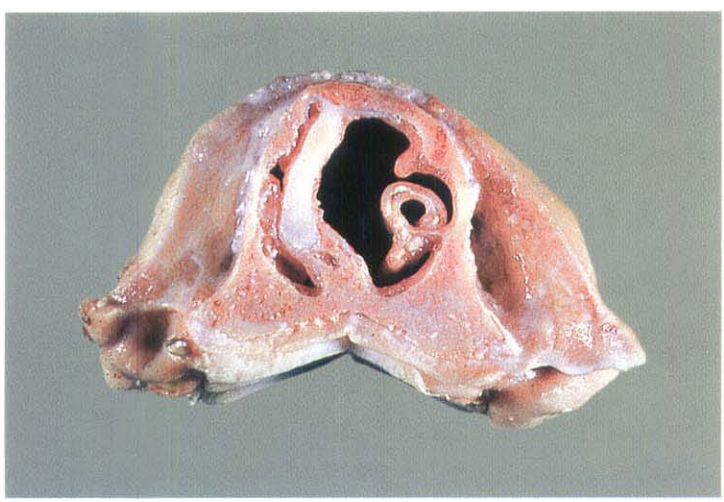
### *Neoplasia*

Primary neoplasms of the respiratory tract can originate from the epithelium or the supporting surrounding structures. Both epithelial and mesenchymal neoplasms, usually malignant, are regularly observed in the upper respiratory tract. In the lower respiratory tract adenocarcinomas of bronchial and bronchiolar-alveolar type are most frequently seen.



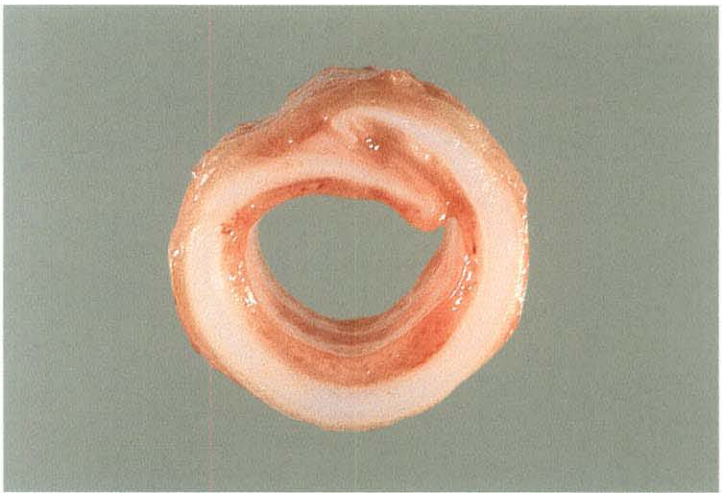
**3-1** Acute fibrinous rhinitis
Head, longitudinal section. Congestion and a fibrinous membrane overlying part of the conchae. Piglet.

**3-2** Mycotic rhinitis and sinusitis
Head, longitudinal section. Severe destructive and exudative rhinitis and sinusitis with gray-white mycotic membranes. Aspergillosis. Dog.

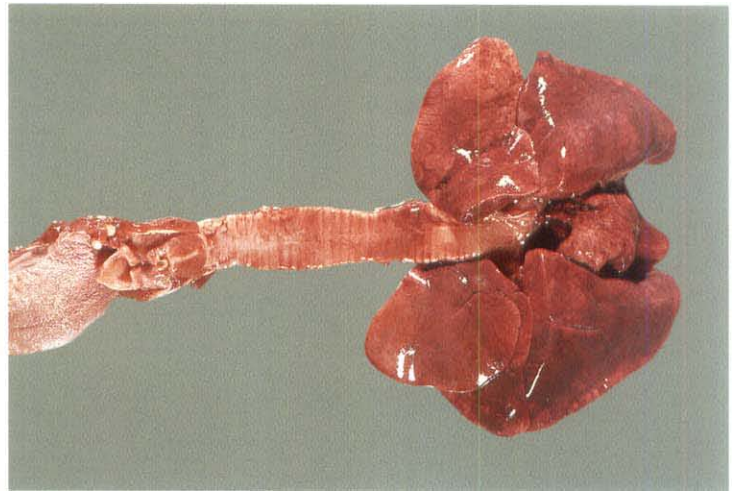


**3-3** Atrophic rhinitis
Nose, transverse section. Chronic rhinitis with atrophy of the conchae and deviation of the nasal septum. Pig.

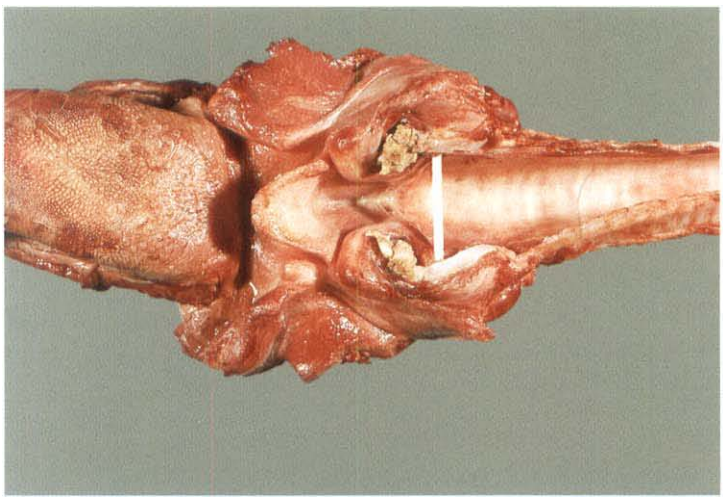
**3-4** Nasal chondrosarcoma
Head, longitudinal section. A large pale tumor mass replaces all the nasal structures. Dog.



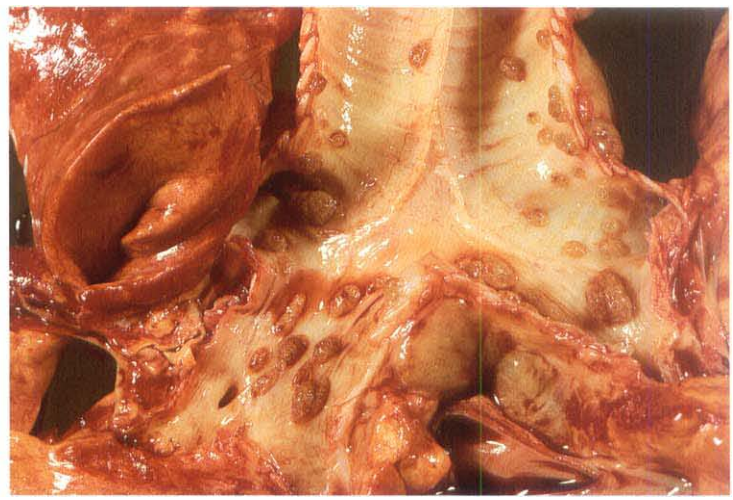
**3-5** Tracheal hypoplasia
Cross-section. Rigid trachea with markedly decreased diameter and overlapping of the dorsal ends of the tracheal cartilage. English bulldog.



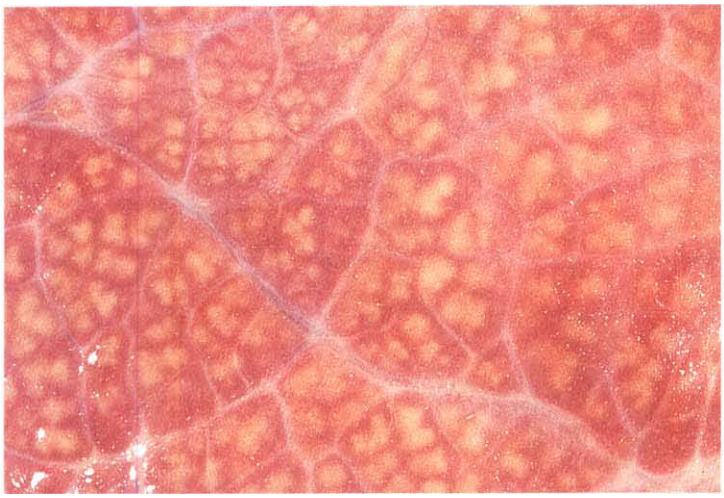
**3-6** Tracheal collapse
Dorsoventral flattening of the trachea with broadening of the dorsal ligament. This syndrome is particularly seen in toy and miniature breeds of dogs.



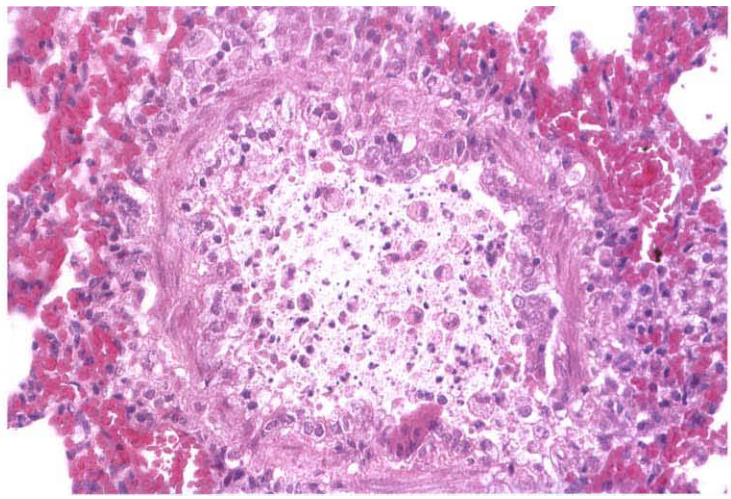
**3-7** Necrotizing laryngitis
Necrotizing inflammation of the arytenoid cartilages caused by *Fusobacterium necrophorum*. Calf.



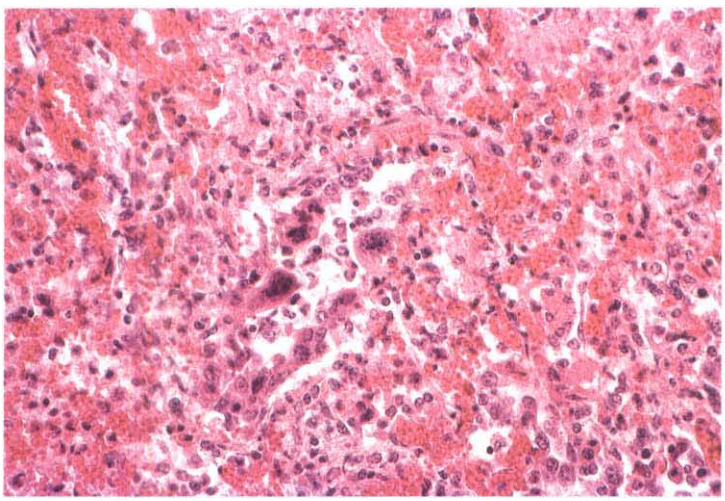
**3-8** Multifocal proliferative tracheitis
Variable sized mucosal nodules that contain parasites and a mild to moderate mononuclear cell reaction. *Oslerus (Filaroides) osleri*. Dog.



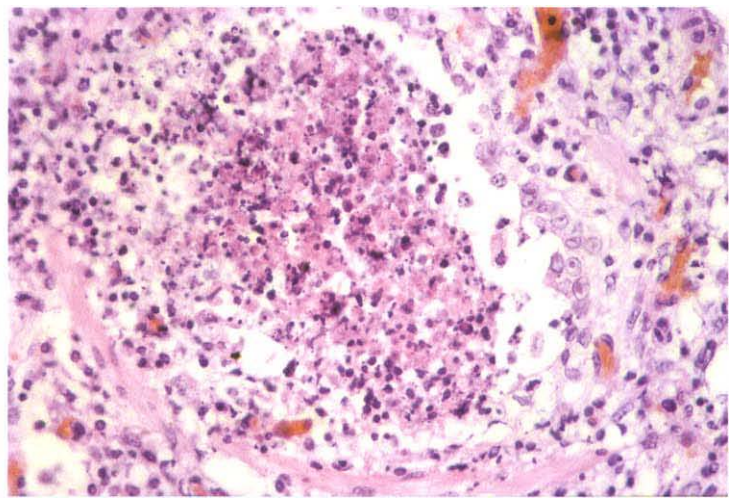
**3-9** Bronchial pattern of pulmonary consolidation
Lung, pleural surface. Consolidated lung tissue. Inflammation of the smaller airways causes a pronounced bronchial pattern. Cow.



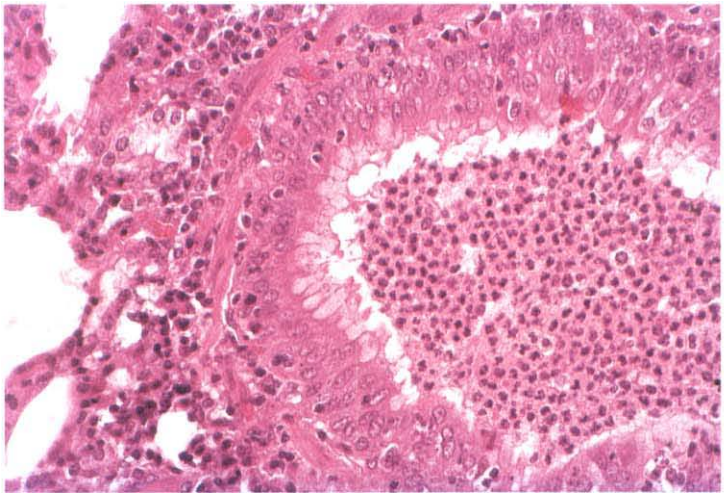
**3-10** Acute bronchiolitis
Hydropic degeneration and karyopycnosis (upper and lower right) of the epithelium as well as exfoliation of the bronchiolar epithelial cells. Dog. HE.



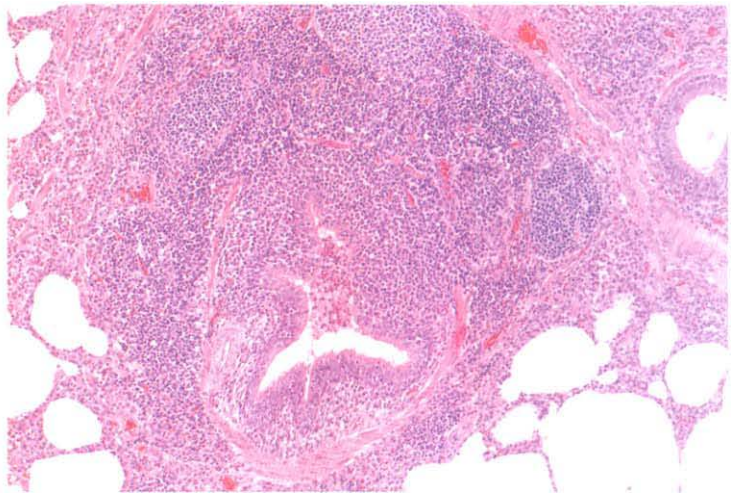
**3-11** Acute bronchiolitis with syncytial giant cells
Bronchiole with some inflammatory cells in the lumen and syncytial giant cells in the epithelial lining; congestion, collapse, and some fluid and cellular exudate in the lung parenchyma. Bovine respiratory syncytial virus. Calf. HE.



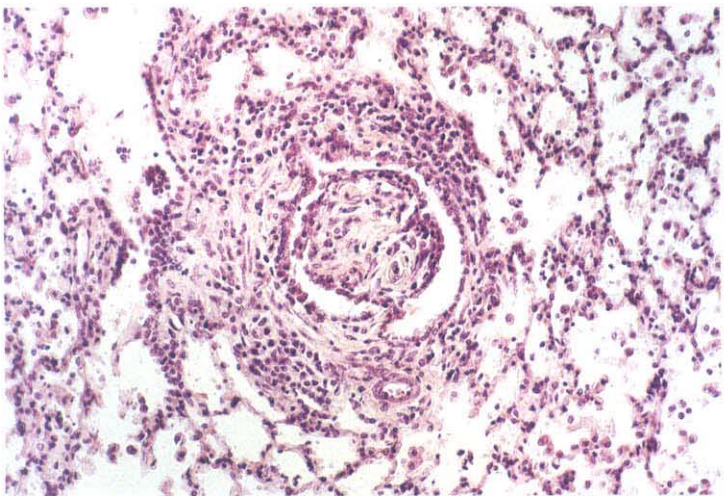
**3-12** Necrotizing bronchiolitis
Necrosis of the bronchiolar epithelium and necrotic debris in the lumen. Intranuclear viral inclusion bodies are present in the still intact bronchiolar epithelium (right). Aujeszky's disease. Piglet. HE.



**3-13** Chronic bronchiolitis
Peribronchiolar mononuclear infiltrate, hyperplasia and goblet cell metaplasia of the bronchiolar epithelium, and neutrophils in the lumen and the epithelium. Chronic obstructive pulmonary disease. Horse. HE.

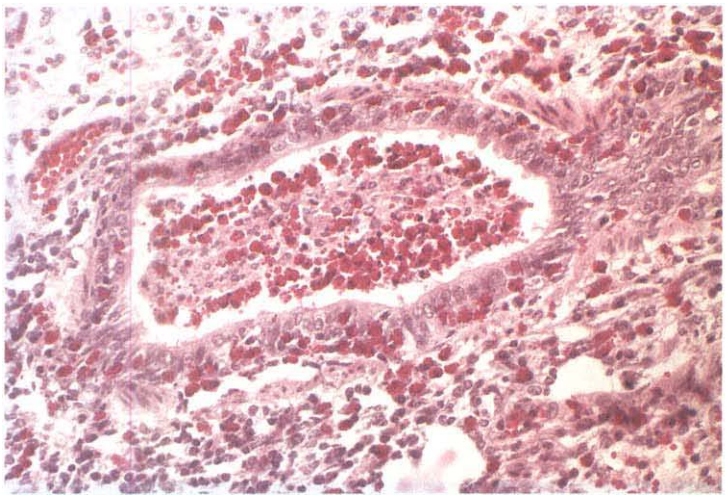


**3-14** Chronic bronchitis with peribronchial lymphoid cuffing
Marked peribronchial lymphoid proliferation with formation of lymphoid follicles. *Mycoplasma hyopneumoniae*. Piglet. HE.

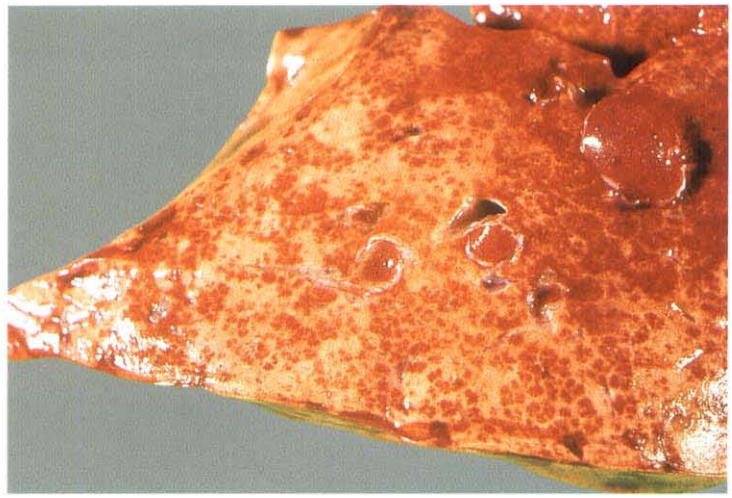


**3-15** Chronic bronchiolitis with bronchiolitis obliterans
A fibroblastic polyp covered by epithelium protrudes into the bronchiolar lumen. Peribronchiolar fibrosis and mononuclear inflammation are also present. Calf. HE.

**3-16** Chronic bronchitis with bronchiectasis
Lung, cut surface. Multiple markedly dilated bronchi filled with mucopurulent exudate; the dilation is due to the accumulation of exudate in the lumen and destruction of the bronchial wall due to chronic bronchitis. The surrounding parenchyma is consolidated. Cow.



**3-17** Eosinophilic bronchiolitis
Eosinophils are present in the bronchiolar lumen, the epithelium and the surrounding parenchyma. This response may be caused by a hypersensitivity type I reaction or migratory parasitic infestation. Foal. HE.

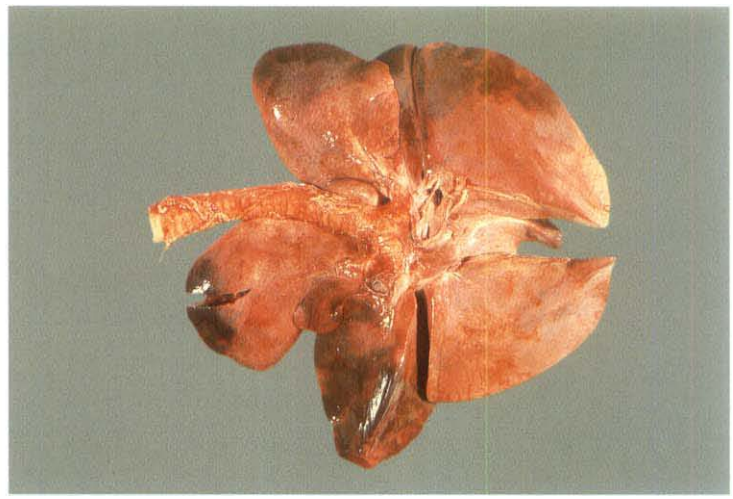


**3-18** Blood aspiration
Lung, cut surface. The branches of the bronchial tree are made clearly visible by the aspiration of blood; the large bronchi contain bloody froth. Pig.

**3-19** Anthracosis
Lung, pleural surface. Emphysematous lung showing many dark deposits of inhaled carbon particles. Dog.

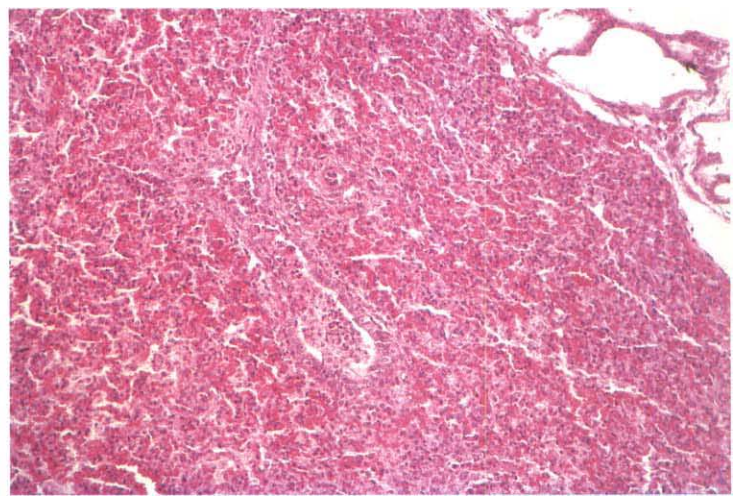
**3-20** Uremic pneumonia
Lung, cut surface. Congestion, edema and metastatic calcification, the latter giving a pumice stone aspect to the lung. Chronic interstitial nephritis. Dog.

**3-21** Passive congestion and pulmonary edema
Lung, cut surface. Congestion and severe edema as fluid oozes from the surface and white froth is present in the bronchus. The lobular pattern is accentuated due to edematous distention of the interlobular septa. Pig.

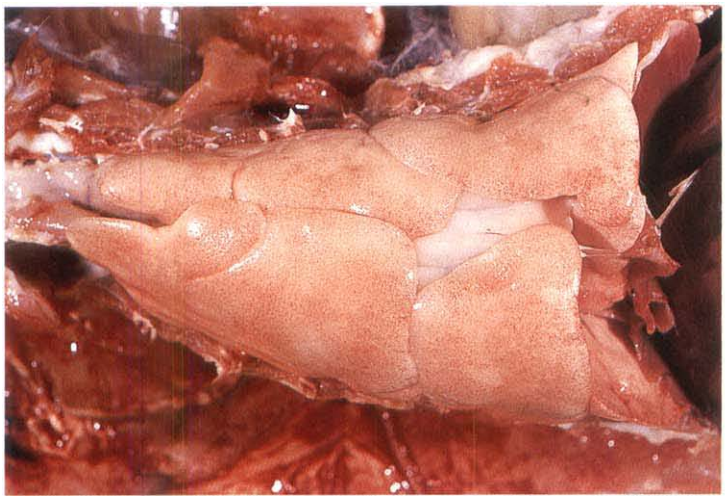


**3-22** Chronic passive congestion and pulmonary infarction
Swollen gray lungs with multiple dark raised infarcts at the periphery. As the lungs have a dual affluent circulation provided by the pulmonary and bronchial arteries, thrombosis or embolism of the pulmonary artery only results in infarction with compromised pulmonary effluent circulation. Dog.

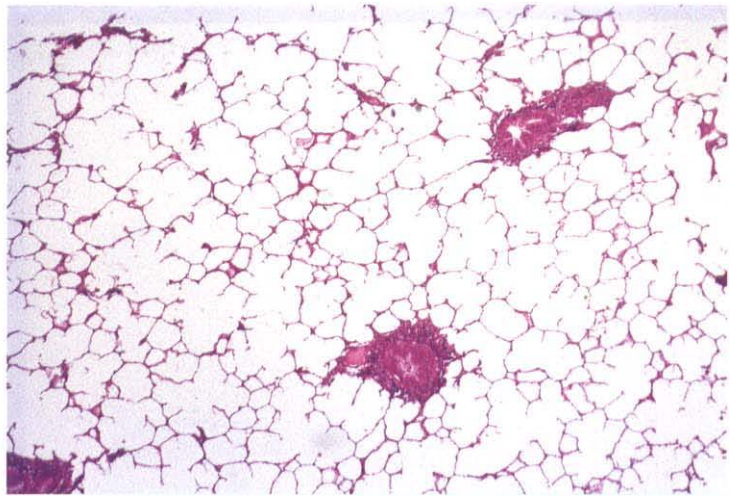
**3-23** Atelectasis
Obstructive atelectasis of a part of the apical lobe. The atelectatic area is depressed and has a dark red color. Dog.



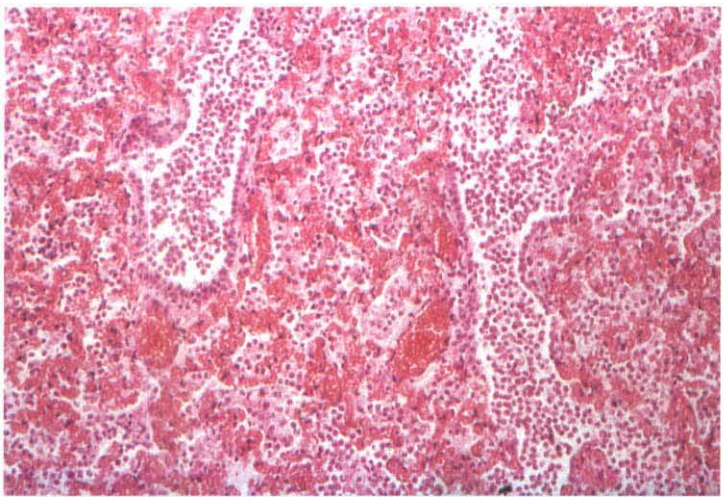
**3-24** Obstructive atelectasis
Obstruction of the bronchiole by exudate and collapse of the adjoining parenchyma. Calf. HE.



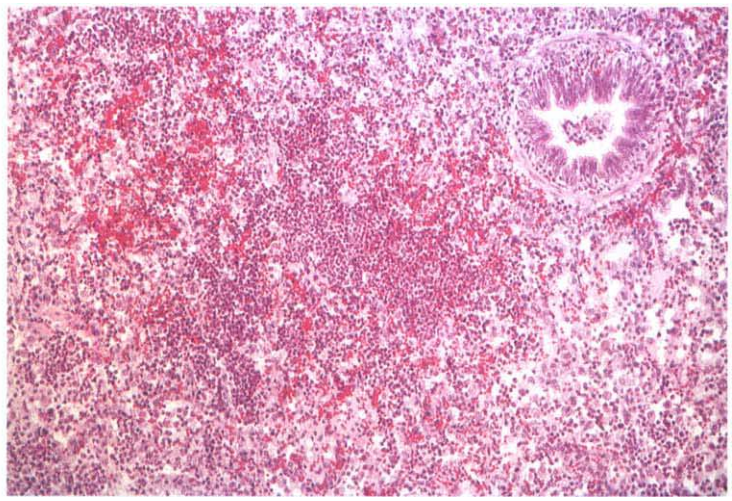
**3-25** Diffuse pulmonary emphysema
Voluminous, pale lungs that fill the thoracic cavity and have distended alveolar sacs. Cat.



**3-26** Pulmonary emphysema
Alveolar emphysema and chronic bronchiolitis. The emphysema is characterized by diffuse distention of the alveoli and is caused by partial obstruction of the bronchioles due to chronic bronchiolitis. Chronic obstructive pulmonary disease. Horse. HE.

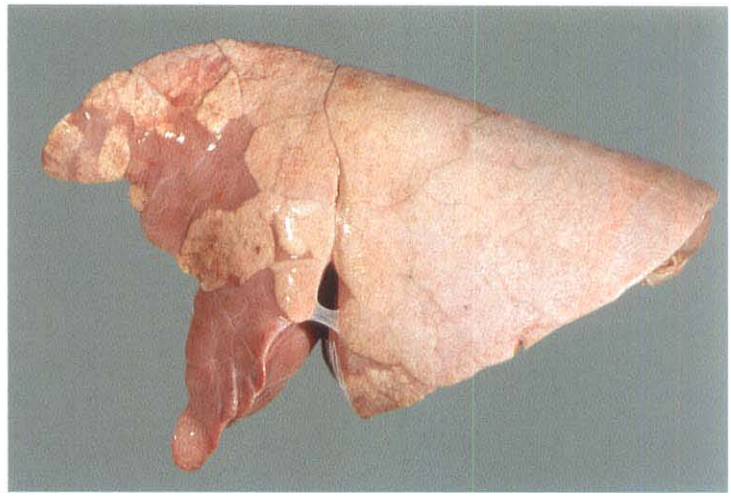


**3-27** Acute catarrhal bronchopneumonia
Intact lung tissue with congestion of the alveolar septa and an exudate consisting of proteinaceous fluid and neutrophils and some macrophages in the alveoli and bronchioles. Calf. HE.

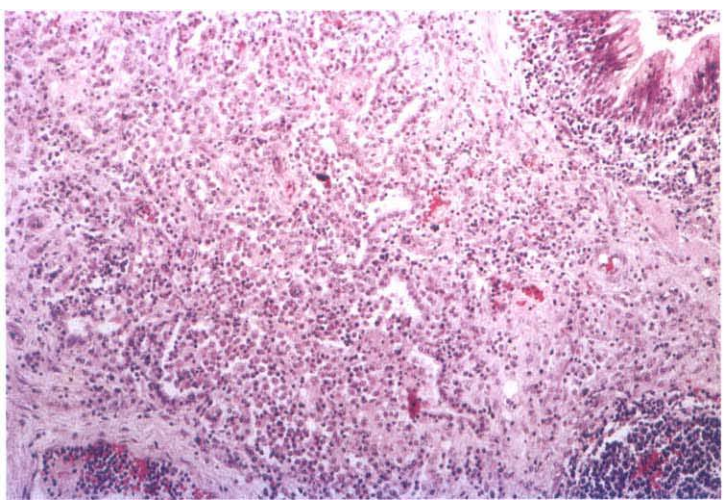


**3-28** Abscessation in catarrhal bronchopneumonia
Focal marked accumulation of neutrophils and subsequent suppurative necrosis of lung tissue; catarrhal pneumonia in the adjacent lung tissue. Calf. HE

**3-29** Suppurative bronchopneumonia
Lung, cut surface. Purulent exudate with suppurative necrosis of lung tissue. *Bordatella bronchiseptica*. Dog.

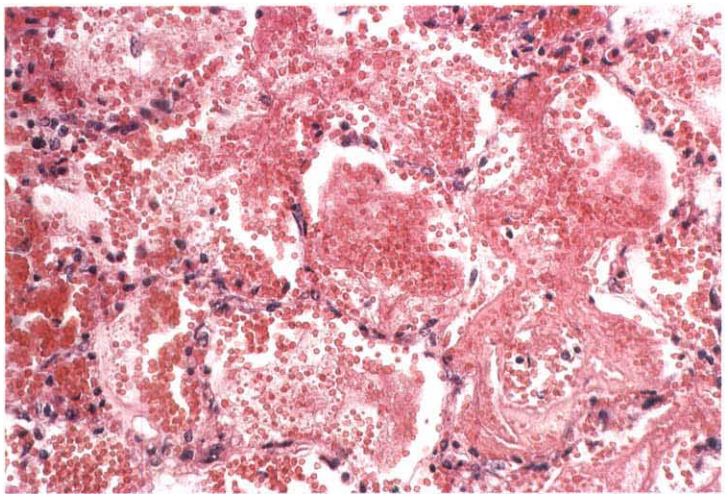


**3-30** Chronic catarrhal bronchopneumonia
Consolidation (gray-red) of cranioventral parts of the apical, cardiac and diaphragmatic lobes. Chronic adhesive pleuritis between the cardiac and diaphragmatic lobes. Porcine enzootic pneumonia. Pig.

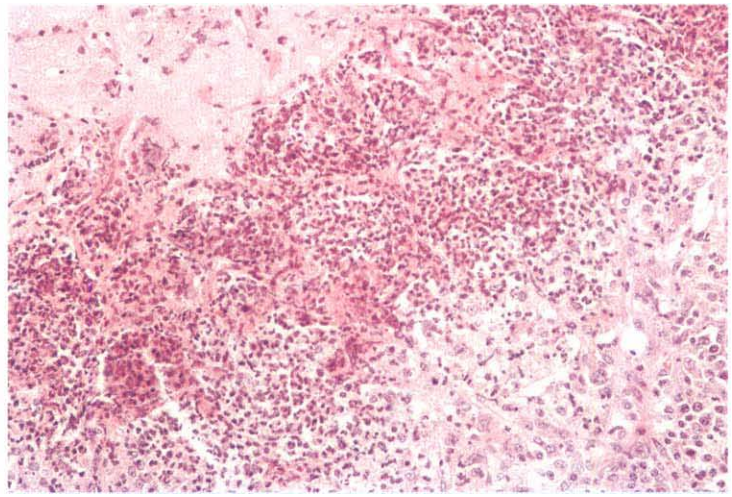


**3-31** Chronic catarrhal bronchopneumonia
Peribronchiolar fibrosis with a slight mononuclear infiltrate. Fibrosis of alveolar septa with type II alveolar cell hyperplasia and a moderate cellular exudate of macrophages and some neutrophils in the alveoli. Pig. HE.

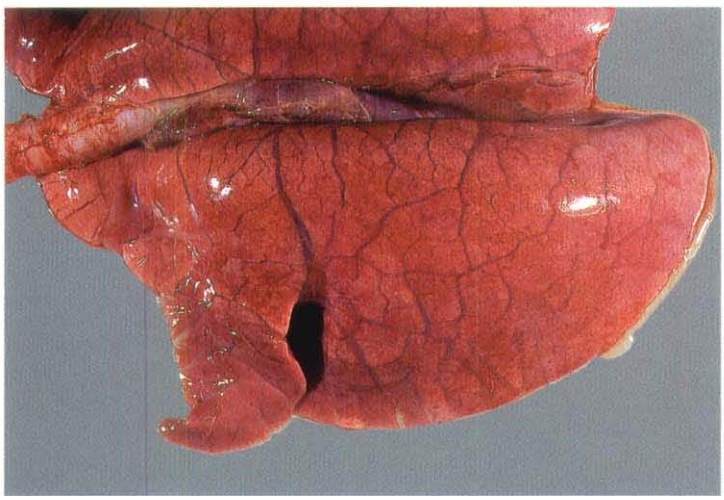
**3-32** Fibrinous pleuropneumonia
The consolidated cranioventral parts of the lung are swollen, firm and red and are covered by a fibrinous plaque. *Actinobacillus pleuropneumoniae*. Pig.



**3-33** Fibrinous pneumonia
Acute stage: fibrinous exudate and erythrocytes in the alveoli. Cow. HE.

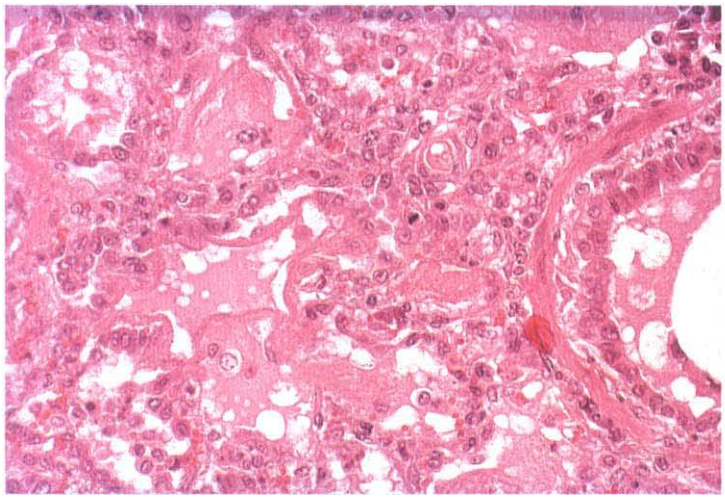


**3-34** Fibrinous-necrotizing pneumonia
Necrosis of lung tissue (upper left) with demarcation zone of rounded and oat-shaped (streaming) phagocytes, as seen in fibrinous pneumonia due to *Mannheimia haemolytica* in sheep and cattle and *Actinobacillus pleuropneumoniae* in swine. HE.

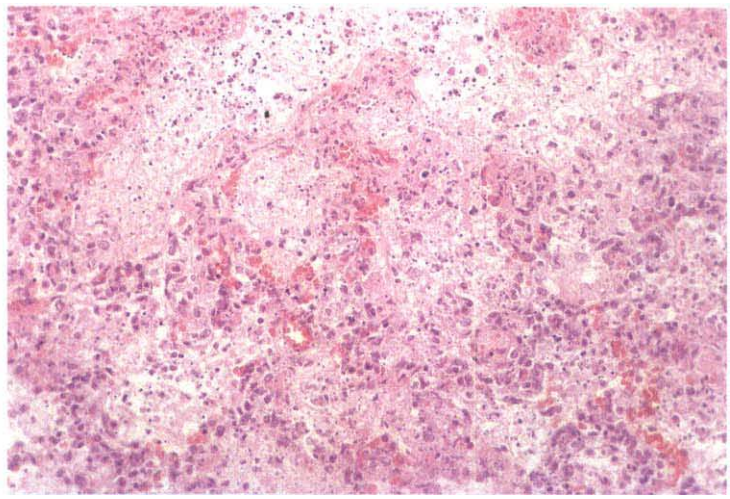


**3-35** Acute serous interstitial pneumonia
The lungs are diffusely affected, swollen and edematous due to the presence of an alveolar and interstitial serous exudate. Circovirus infection. Pig.

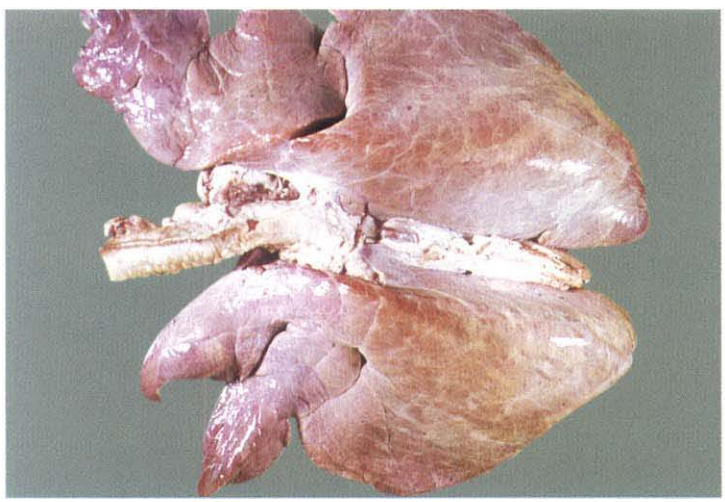
**3-36** Acute serous interstitial pneumonia
Lung, pleural surface. All pulmonary lobes are consolidated and red with secondary interstitial emphysema. Bovine pulmonary edema and emphysema (fog fever). Cow.



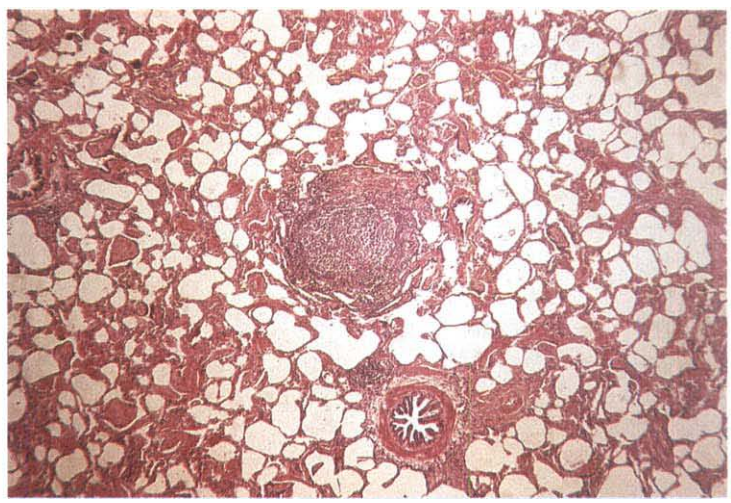
**3-37** Acute serous interstitial pneumonia
The consolidated pneumonic areas are characterized by a protein rich exudate in the alveoli and bronchiole, the formation of hyaline membranes and epithelialization of the alveolar lining by alveolar type II cell hyperplasia. Cow. HE.



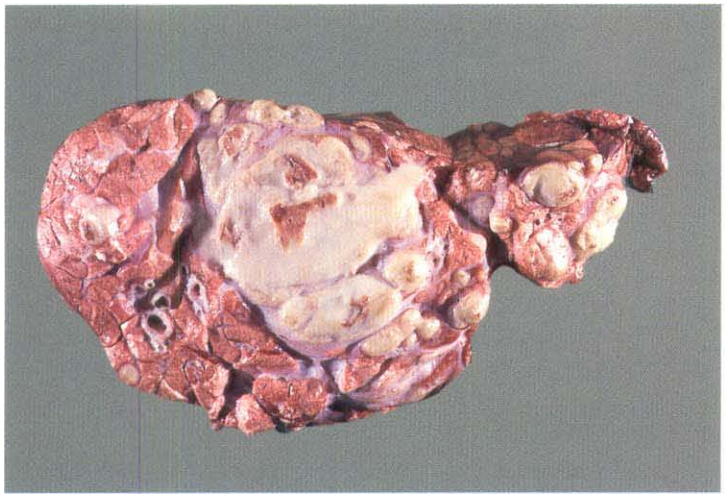
**3-38** Acute fibrinous-necrotizing interstitial pneumonia
The consolidated lung tissue shows necrosis of alveolar septa and a proteinaceous fibrinoid, almost non-cellular exudate in the alveoli. Grossly the lungs were diffusely affected. *Herpes felis*. Cat. HE.



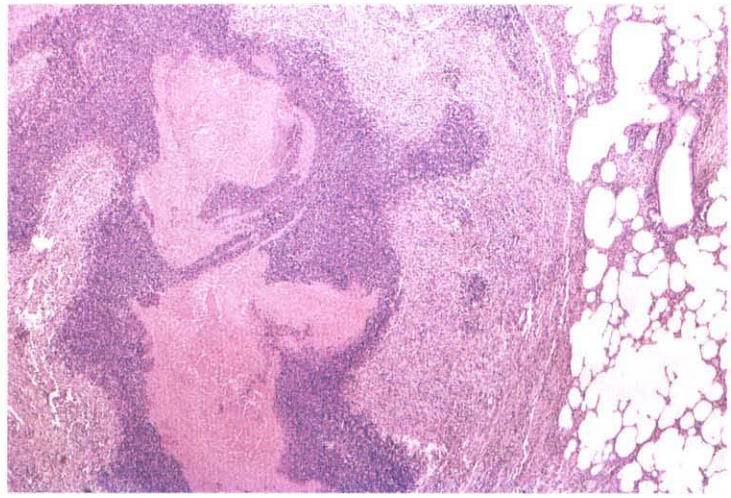
**3-39** Chronic interstitial pneumonia
Pale-gray, aerated, voluminous and non-collapsible lungs that have a meaty consistency and increased weight. Cow.



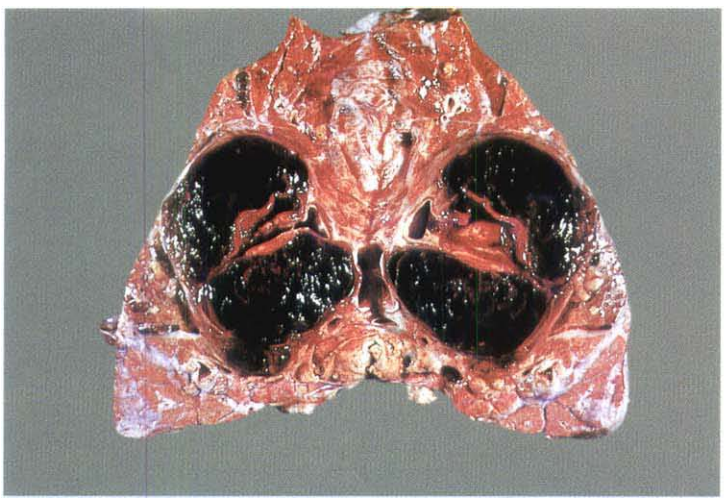
**3-40** Chronic interstitial pneumonia
Aerated lung tissue with diffuse thickening of the interstitium due to fibrosis, increased cellularity and increase of smooth musculature; focal lymphoid aggregate. Cow. HE.



**3–41** Metastatic pneumonia
Lung, cut surface. Several pneumonic foci, consisting of central coagulation necrosis surrounded by pus. Necrobacillosis. Cow.

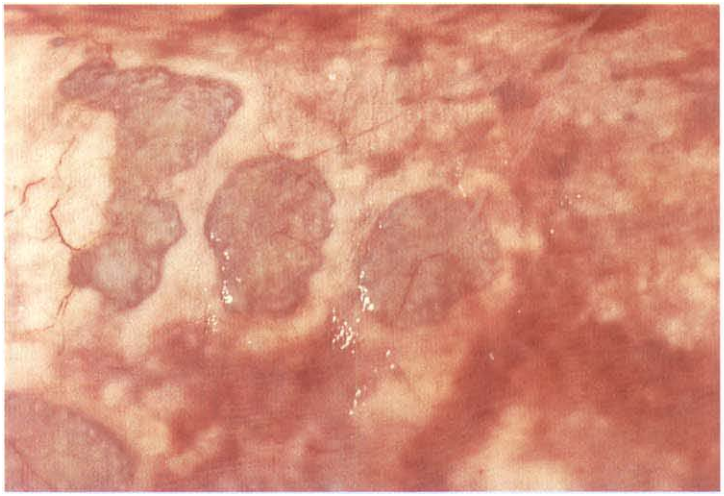


**3–42** Metastatic pneumonia
Coagulation necrosis surrounded by a demarcation zone of cellular exudate (dark blue) and granulation tissue. Necrobacillosis (*Fusobacterium necrophorum*). Cow. HE.

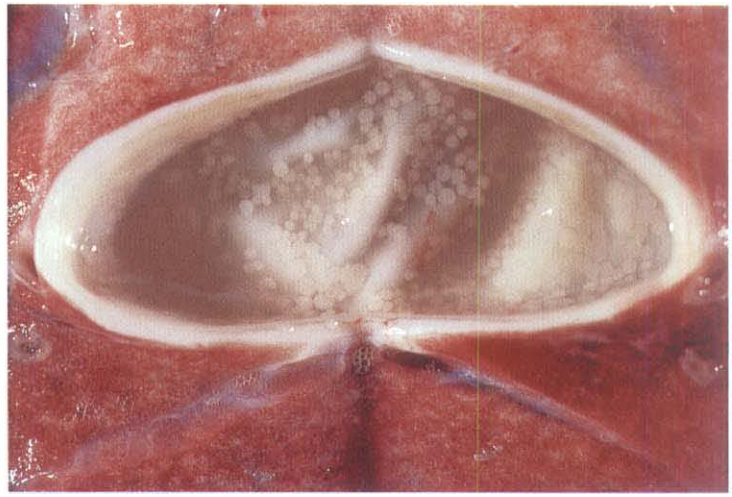


**3–43** Metastatic pneumonia with pulmonary hemorrhage
Lung, incised through the lesion. Pulmonary hemorrhage due to metastatic pneumonia with subsequent necrotizing arteritis, aneurysm formation and rupture of the pulmonary artery. Necrobacillosis (*Fusobacterium necrophorum*). Cow

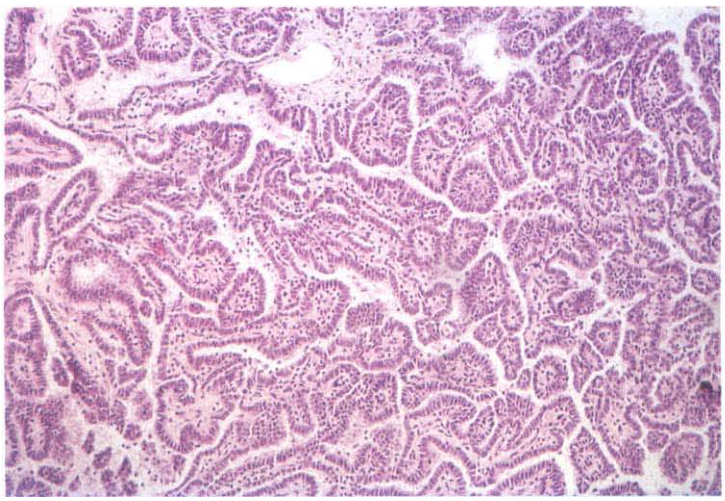
**3–44** Avian tuberculosis
Lung, cut surface. Multiple gray-white hyaline tuberculous foci that have spread along the interstitium; no evidence of caseous necrosis. Avian tuberculosis (*Mycobacterium avium*). Pig.



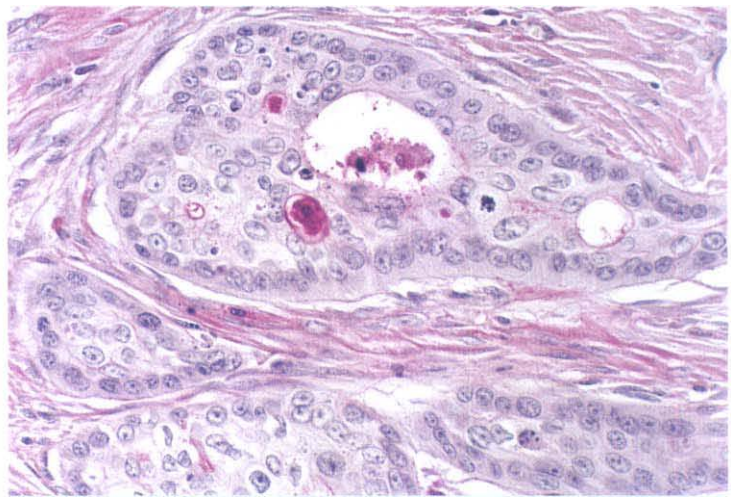
**3-45** Verminous pneumonia
Lung, diaphragmatic lobe. Subpleural gray-white pneumonic nodules produced by the adult worms, eggs and larvae of *Muellerius capillaris*. Sheep.



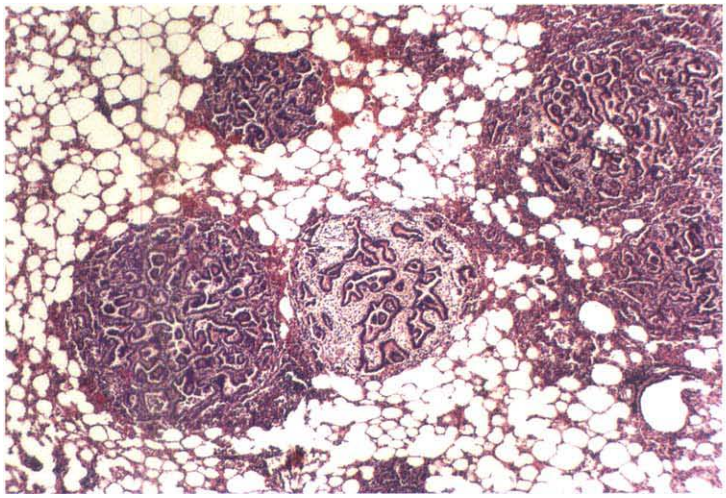
**3-46** Echinococcosis
Lung, incised fertile hydatid cyst with many brood capsules; the cyst is surrounded by a fibrous capsule. Cow.



**3-47** Adenocarcinoma, bronchiolo-alveolar pattern
Complex papillary growth covered by a single layer of well-differentiated columnar cells with basal nuclei. Dog. HE.



**3-48** Adenocarcinoma, bronchial pattern
The tumor is frequently seen in cats and characterized by solid areas or multilayered tubular structures of pale large cells; often goblet cells and sometimes ciliated epithelial cells are present. Metastases occur frequently, particularly to the digits, and usually cause the first clinical signs. Cat. PAS.



**3-49** Pulmonary adenomatosis (jaagsiekte)
Lung, multiple nodules showing adenomatous and papillary growth. Sheep. HE.

**3-50** Metastatic carcinoma
Metastases of a mammary carcinoma in the lungs. Cat.

Chapter 4

# The urinary system



## THE URINARY SYSTEM

The urinary system includes the kidneys and lower urinary tract. Lesions are rather common in domestic animal species. Most of them concern inflammatory reactions, but congenital cysts and hydronephrosis also may be frequently encountered. Degenerative processes and primary neoplasms are less common.

### *The kidneys*

#### Degenerative processes

Degenerative lesions, mainly of convoluted tubules (tubulonephrosis or acute tubular necrosis), but also of glomeruli (glomerulopathy) are seen in:

- septicemia;
- intoxications (nephrotoxic tubular necrosis);
- anoxemia, especially in cases of shock (ischemic necrosis); and
- increased or abnormal depositions, e.g. concrements, proteins, pigments, or lipids.

Rarely, renal cortical necrosis due to a generalized Shwartzman phenomenon or renal vein thrombosis may occur.

***Amyloidosis***

*Glomerular amyloidosis* is a major glomerulopathy (glomerulonephrosis), but more often amyloid deposits occur in the medullary interstitial tissue and arterial walls. The glomerular amyloid involvement, however, has more clinical impact due to impairment of the blood flow through the glomerular tuft and impaired filtration rate.

#### Inflammatory processes

In general, renal inflammatory processes can be divided into those resulting from glomerulopathy and those resulting from tubulointerstitial lesions. Most *inflammatory glomerular* lesions are associated with deposits of *immune complexes. Bacterial embolization* may result in focal glomerulitis.

***Glomerular immune complex depositions***

Depending on their method and place of deposition, various patterns may develop which are associated with different

histopathological types of glomerulonephritis. Just as glomerular amyloidosis also immune complex glomerulonephritis is often associated with loss of filtration selectivity resulting in widened tubular lumens filled with protein-containing contents.

***Secondary glomerular involvement***

When *tubulointerstitial processes* prevail a secondary glomerular involvement may occur, especially when the processes are associated with chronic loss of nephrons and adaptive phenomena in remnant nephrons. A primary glomerular involvement can also be followed by tubulointerstitial lesions.

***Tubulointerstitial diseases***

Tubulointerstitial diseases are mainly due to infectious agents or toxins. *Chronic interstitial nephritis* (CIN) is a common cause of renal failure. In cases of *inner medullary* (papillary) *necrosis* or inflammation (*pyelonephritis*) secondary cortical lesions often develop.

*Focal cortical lesions* often represent infarcts and inflammatory processes (or their scars) resulting from *embolism*. In production animals this is frequently seen in association with septic emboli.

In glomerular lesions (degenerative and inflammatory) as well as in tubulointerstitial nephritis the gross and histopathological features of the kidneys are the result of tubular widening, tubular cellular loss and increase of interstitium (inflammatory cells, fibroblasts and matrix).

#### Neoplasms of the kidney

*Primary renal neoplasms* consist of renal tubular carcinomas, Wilm's tumors and pelvic transitional epithelial cell tumors. In the kidneys metastatic tumors are common, especially of the lymphoid system.

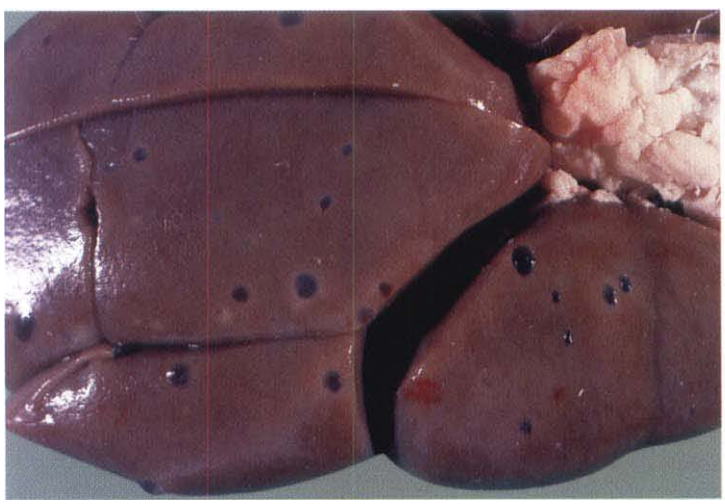
## The lower urinary tract

#### Inflammatory lesions

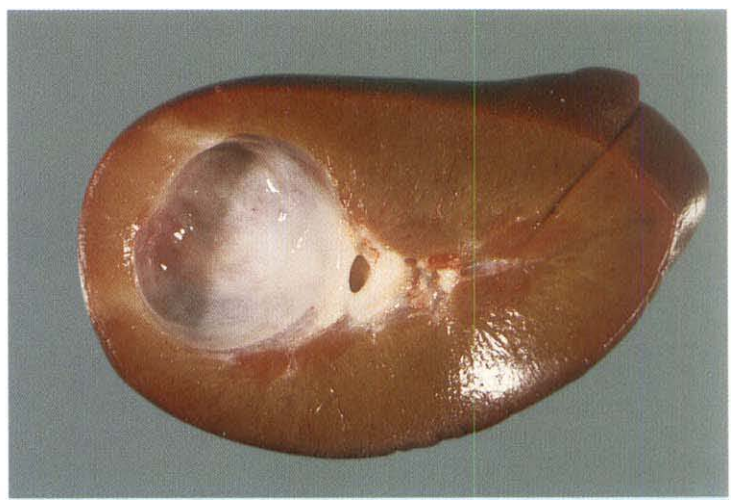
In the *lower urinary tract*, beginning with the pelvis, inflammatory lesions are common. Problems may arise after obstruction or due to ascending infections. In dogs the latter may be promoted by congenital abnormalities in the ureteral-bladder junction.

#### Neoplasms of the lower urinary tract

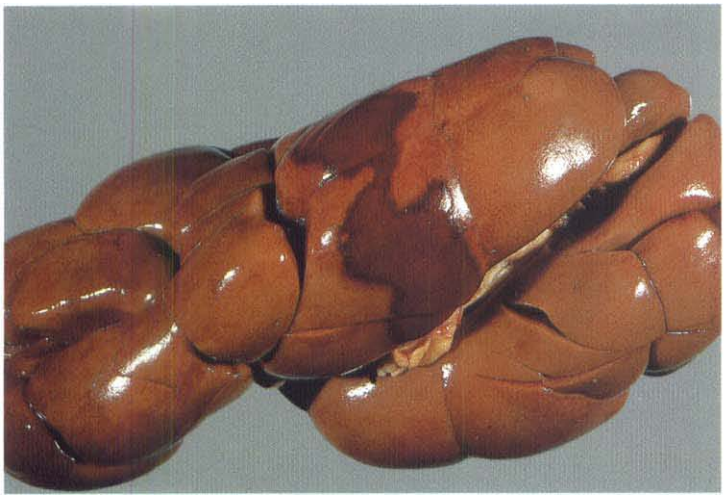
Most *neoplasms* of the bladder and urethra are transitional epithelial cell tumors. The lower urinary tract tumors may be associated with secondary hydronephrosis.



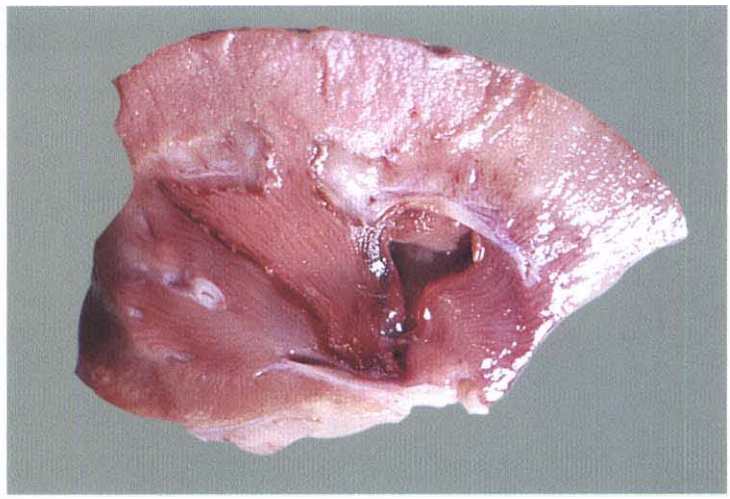
**4–1** Cortical cysts
Renal surface. Multiple small prominent cysts in the cortex, due to dilation of parts of the nephrons (Bowman's capsules and/or tubules) associated with accumulation of glomerular filtrate. In other cases, the cysts may be solitary and/or larger; most are incidentally found congenital lesions. Slaughter cow.
Note that in some animals hereditary deleterious cysts may occur which increase in number and size during aging, such as in the autosomal dominant polycystic kidney disease (PKD) of Persian cats.



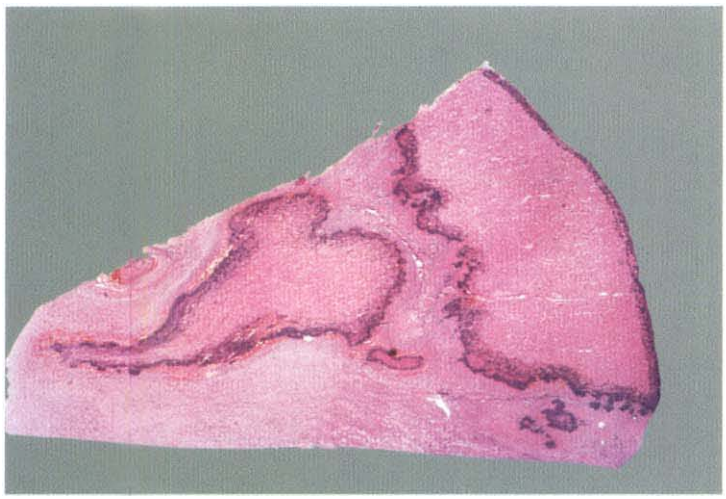
**4–2** Medullary cyst
Renal cut surface. A single large cyst in the medulla. The cysts may be multiple and smaller. They are usually the result of dilated collecting tubules and represent incidentally found congenital lesions. The fibrosis in the overlying cortex of the present case may be secondary to the expansion of the cyst. Slaughter pig.



**4-3** Infarct
Renal surface. Large red-colored hemorrhagic infarct due to subtotal thrombotic occlusion of renal artery branch. The necrotic area is slightly raised and sharply defined from surrounding tissue. On cut surface wedge-shaped lesions involving cortex and medulla are found. Cow suffering from thromboendocarditis.

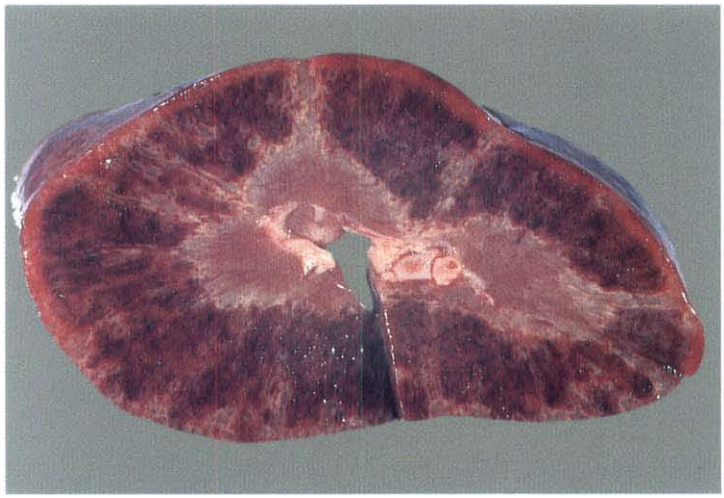


**4-4** Infarct
Renal cut surface. Large anemic infarct due to total thrombotic occlusion of renal artery branch. The necrotic area involving areas of the cortex and medulla, is pale-colored, slightly raised and sharply defined from surrounding tissue by a hemorrhagic zone. Cow suffering from thromboendocarditis.

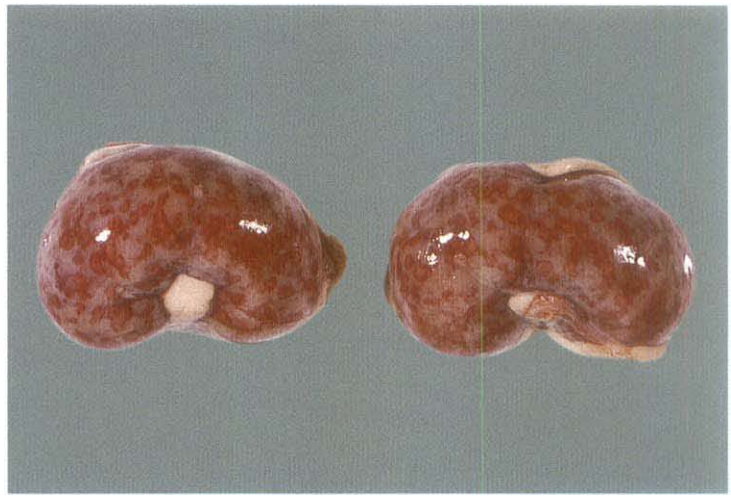


**4-5** Infarct
Histopathological specimen of former photograph. Note pale necrotic tissue in cortex and medulla surrounded by a clearly blue and red colored demarcation zone. HE.

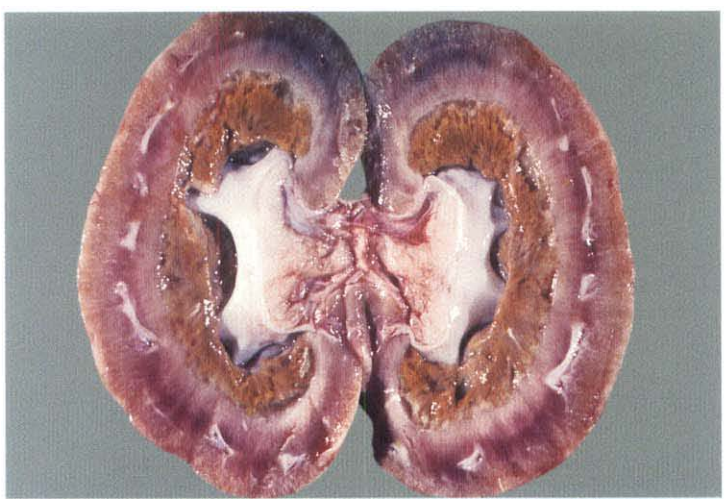
**4-6** Subinfarct
Cut surface of two renal lobes. Yellowish-white mottled area in the cortex and subcortical layer. Ischemic necrosis and dystrophic calcification of the highly susceptible proximal tubules, resulting from incomplete vascular occlusion. Frequently found with full infarcts (see Fig. 4-3). Thromboendocarditis. Cow.



**4–7** Cortical necrosis
Renal cut surface. Diffuse hemorrhagic necrosis of the greater part of the renal cortex as a consequence of glomerular capillary thrombosis (disseminated intravascular coagulation). Possibly secondary to endotoxemia (lipopolysaccharides) of Gram-negative bacteria (Schwartzman phenomenon). Pig.



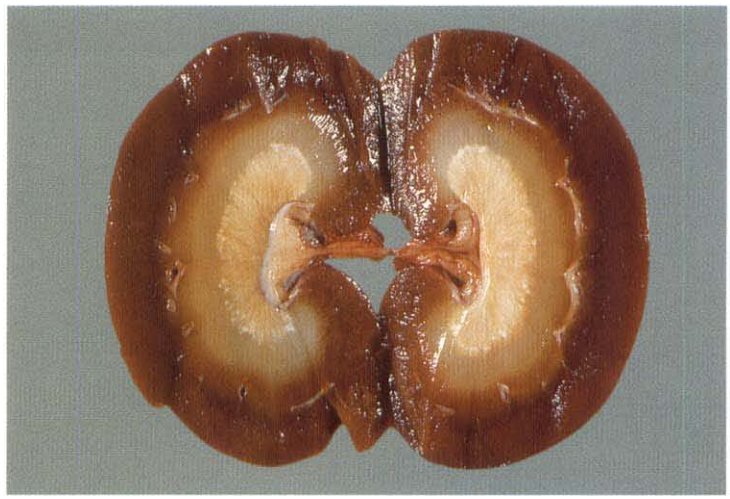
**4–8** Cortical necrosis
Multiple areas of necrosis and hemorrhage in the renal cortex that are readily visible. Herpes virus infection. Newborn puppy dog.



**4–9** Medullary necrosis
Renal cut surface. Diffuse necrosis of the renal crest (inner medulla). Such a lesion may be found after long term treatment with analgesic drugs, which may be associated with blockade of prostaglandin synthetase and associated renal medullary hemostasis. Dog.

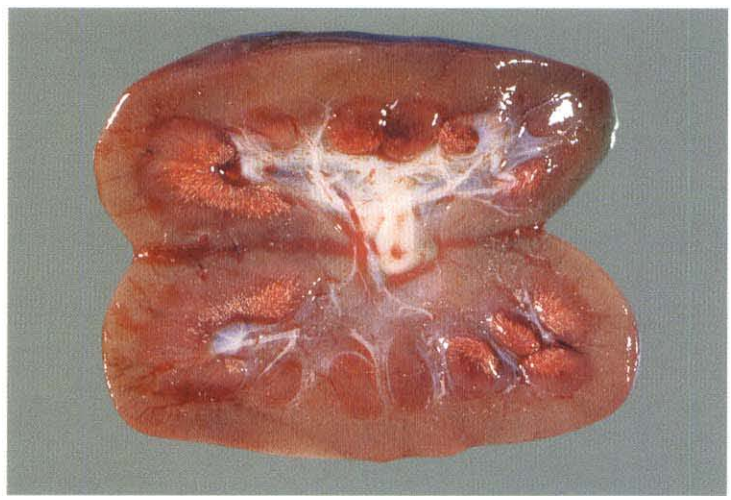
**4–10** Lipofuscinosis
Dark brown discoloration of the renal cortex. Characteristic reticulate design of the renal surface (below) and radial dark lines in the cortex on cut surface. Microscopically, lipofuscin pigment is present in lysosomes of the proximal tubular epithelial cells. Slaughter cow.

**4–11** Lipoid nephrosis
Renal surface. Swollen and pale renal lobes with a typical pale yellow reticulate design on the surface. Microscopically, anisotropic lipids accumulate in the proximal tubular epithelial cells. This appeared to result from severe impairment of glomerular perm-selectivity due to amyloidosis. Cow.
In other cases of renal lipidosis tubular accumulation of neutral fat can occur pathologically (fatty degeneration with isotropic lipids, for instance in fasting dwarf breed puppy dogs), or physiologically (in adult cats, or in the inner cortex of cattle in pregnancy).

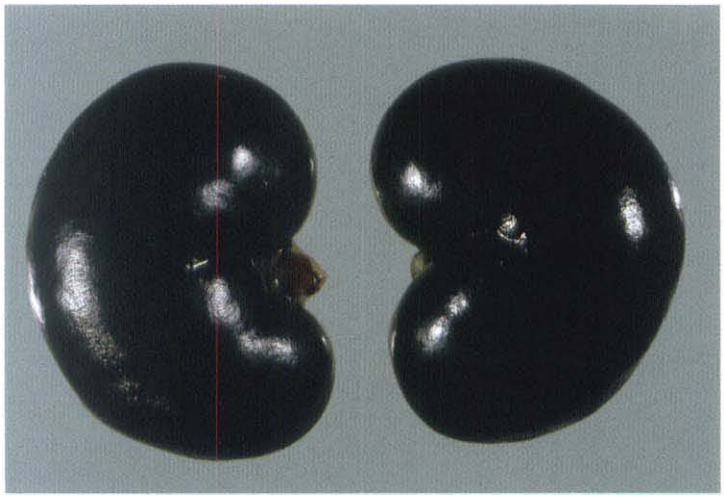


**4–12** Medullary calcification
Renal cut surface. White discoloration of the papillae due to peritubular deposition of calcium salts in basement membranes and interstitial tissue (dystrophic calcification). Potentially it might cause polyuria. In most cases, however, it is an incidental finding. Dog.

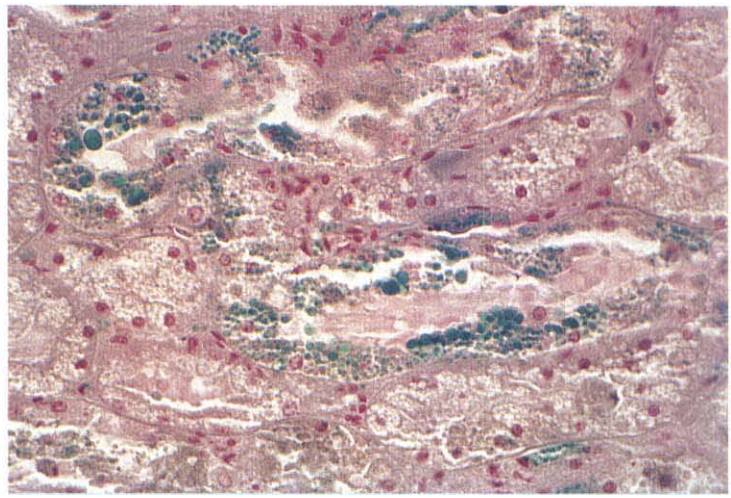
**4–13** Gout
Kidney and heart of bird with deposition of uric acid and urate crystals in the kidney and on the epicardium. Domestic fowl.



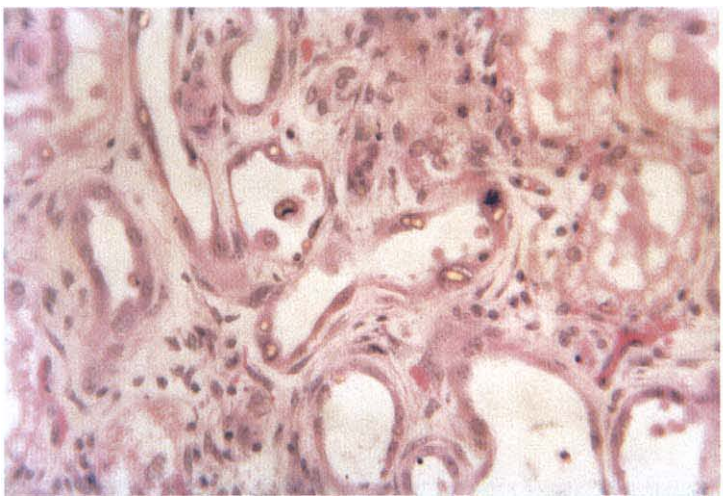
**4–14** Uric acid concrements
Renal cut surface. Yellow radial striation of renal papillae due to intratubular deposition of uric acid and urate. The lesion is associated with increased nuclear catabolism and dehydration. It is frequently seen in starving and hypoglycemic piglets. Newborn piglet.



**4-15** Hemoglobinuric nephrosis
Renal surface. Black discoloration of the kidneys due to concentration of (met)hemoglobin. Massive acute hemolysis caused by chronic copper poisoning. Sheep.

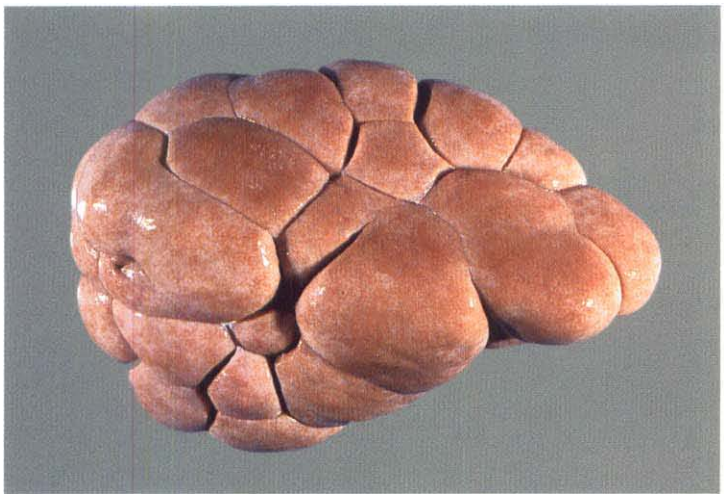


**4-16** Hemoglobinuric nephrosis
Renal cortex. Proteinaceous material in tubular lumina resulting from hemoglobin filtration. Green-blue homogeneous globules (hyaline droplets) in tubular epithelial cells, are due to reabsorption and lysosomal accumulation of the filtered hemoglobin. Moreover, hydropic degeneration and necrosis of tubular cells. Hemoglobinuria caused by chronic copper poisoning. Sheep. Fast blue stain for hemoglobin.

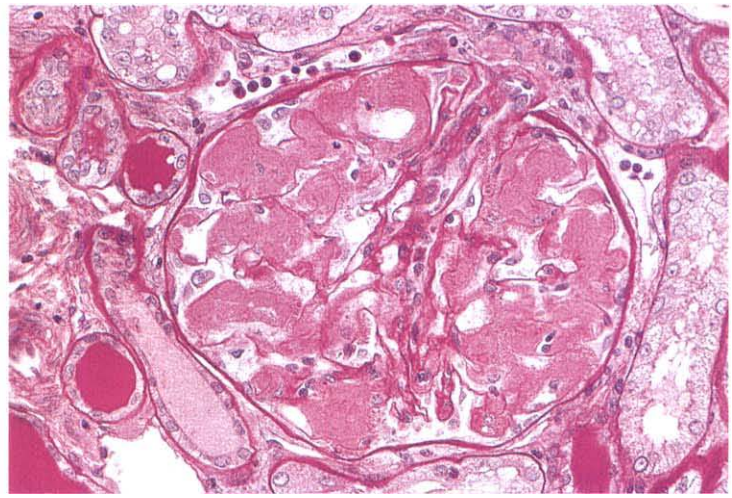


**4-17** Chronic toxic tubulonephrosis
Renal cortex. Dilated tubules lined by flattened epithelial cells with variable sized nuclei containing yellowish intranuclear inclusion bodies (lead protein complexes). Reactive fibrosis and infiltration of inflammatory cells. Chronic lead poisoning. Calf. HE.

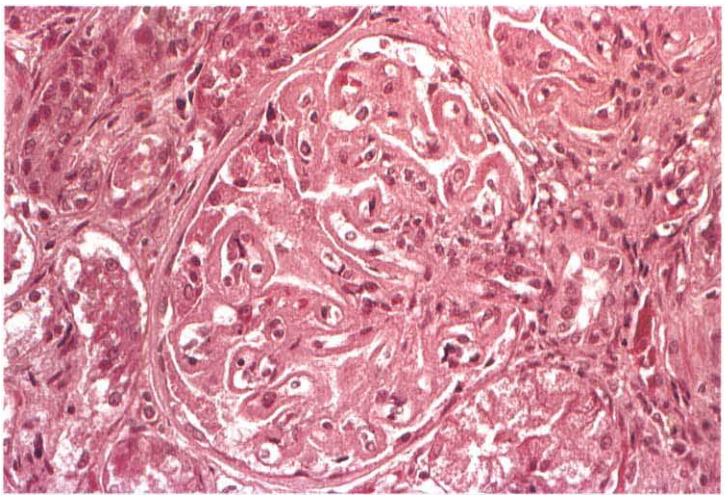
**4-18** Septic tubulonephrosis
Renal cut surface (left) and surface (right). The kidneys are large and pale due to tubular degeneration. Microscopically the changes may vary from cloudy swelling to necrosis of epithelium, mainly of cortical tubules. Petechiae are prominent (right). Bacteremia. Sheep.



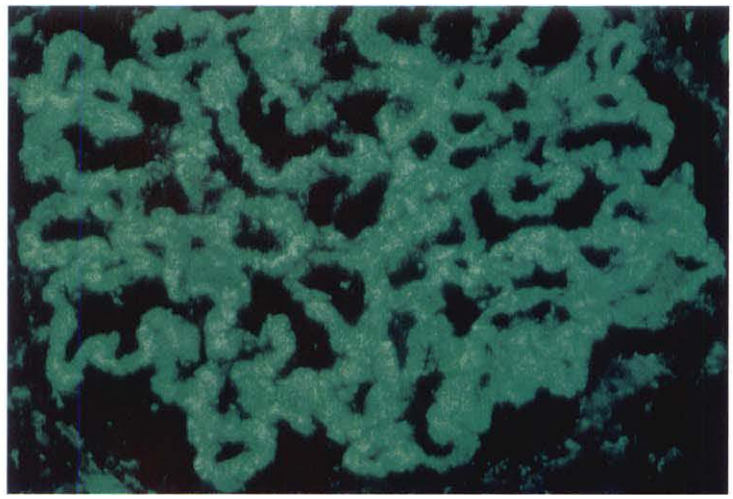
**4–19** Chronic glomerular amyloidosis
Renal surface. Enlarged kidney with swollen, whitish-yellow, discolored and irregularly surfaced lobes, caused by dilation and degeneration of tubules, interstitial inflammation and fibrosis. These tubulointerstitial lesions are secondary to glomerular dysfunction resulting from amyloid deposition. AA-amyloidosis. Cow.



**4–20** Glomerular amyloidosis
Deposition of amyloid on the inner aspect of the violet stained glomerular basement membrane. In some places penetration of the basement membrane by small spicular projections of amyloid at its outer aspect has occurred. Neighboring tubules contain pink proteinaceous material and violet casts. AA-amyloidosis. Dog. PAS-stain for neutral sugars and glycoproteins.

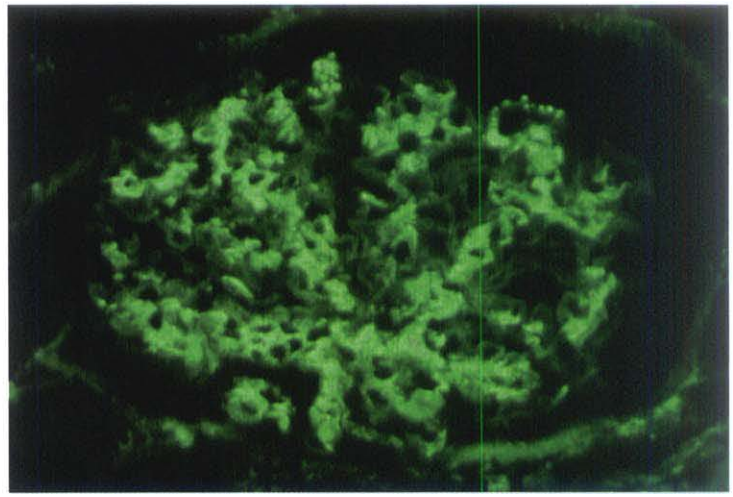


**4–21** Membranous glomerulonephritis
Thickening of the capillary walls of a glomerulus due to deposition of immune complexes, and thickening of the glomerular basement membrane. Patent capillary lumina. Lack of hypercellularity. Dog. HE.

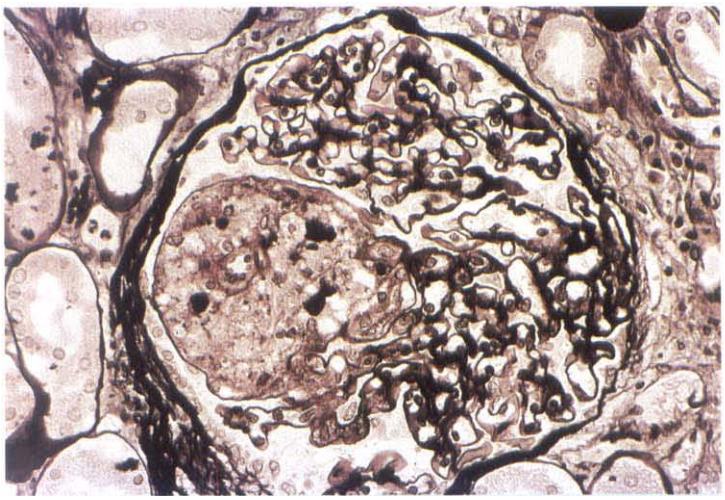


**4–22** Membranous glomerulonephritis
Glomerulus. Granular fluorescence along the glomerular basement membrane due to deposition of immune complexes. In most spontaneous cases it represents an idiopathic lesion. Dog. Rabbit antidog IgG immunofluorescence.

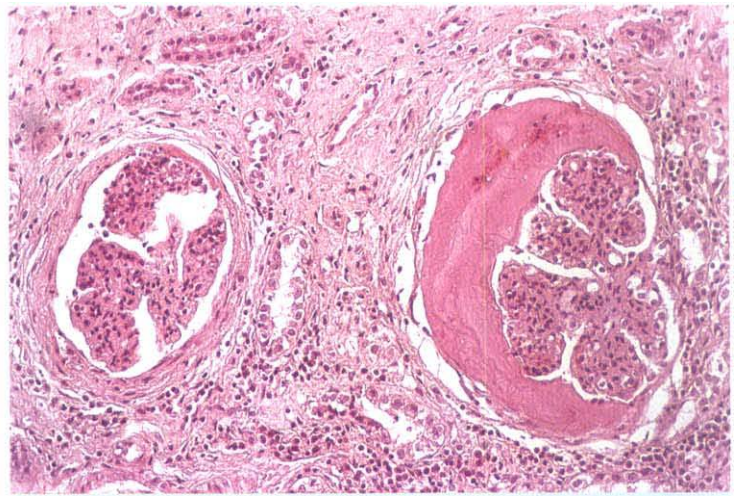
**4-23** Membranoproliferative-sclerosing glomerulonephritis
Segmental thickening of the glomerular basement membrane with narrowing of capillary lumina, and proximally an increase of mesangial matrix (sclerosis) and proliferation of mesangial cells. Adhesions (synechiae) between the glomerular tuft and Bowman's capsule. Dog. Jones' methenamine silver stain.



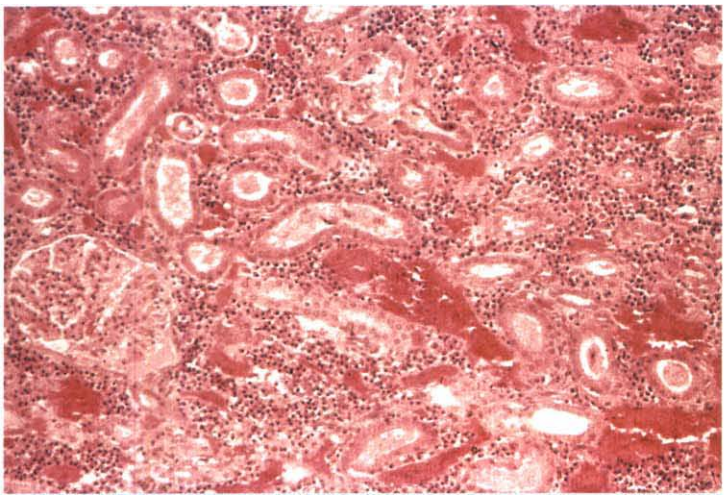
**4-24** Membranoproliferative glomerulonephritis
Granular fluorescence along some segments of the glomerular capillary tuft and mesangial (centrally located) accumulation of fluorescent material. Dog. Rabbit antidog IgG immunofluorescence.



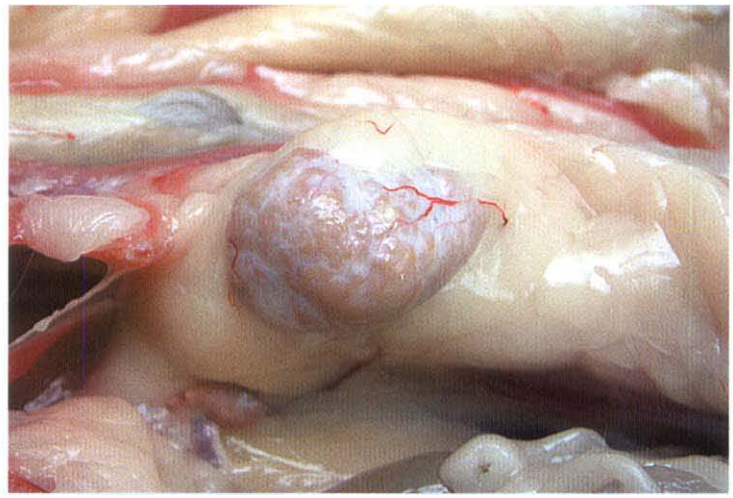
**4-25** Glomerular lipidosis
Glomerulus. Mesangial accumulation of large lipid-containing foam cells in a segment of the glomerular tuft. Note the localization within the superficial black-stained basement membrane. Incidental finding in dogs. Jones' methenamine silver stain for basement membrane.



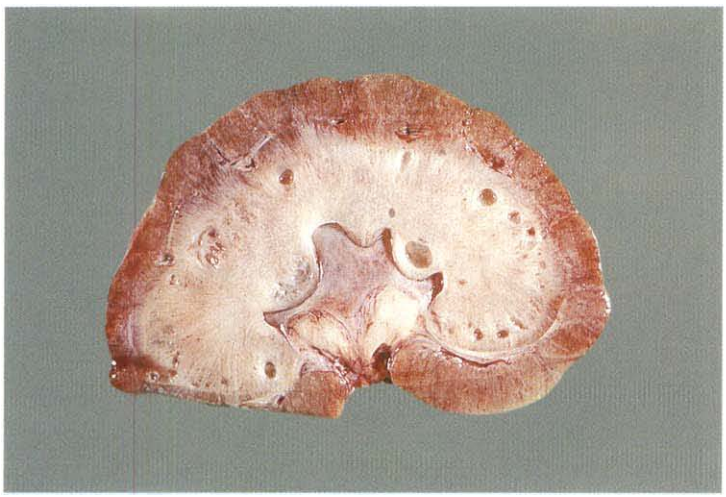
**4-26** Exudative glomerulonephritis
Hypercellularity of the glomerular tufts (intracapillary glomerulonephritis). A semilunar mass of exudate within Bowman's capsule of the right glomerulus, containing serum, fibrin and some neutrophils (extracapillary glomerulonephritis) demonstrates that subendothelial immune complexes have initiated complement activation and subsequent exudative inflammation. The left glomerulus shows a proliferative extracapillary reaction of the Bowman's capsule. There is prominent interstitial fibrosis. The lesion frequently is found in swine with necrotic skin lesions (porcine dermatitis and nephropathy syndrome (PDNS)). Pig. HE.



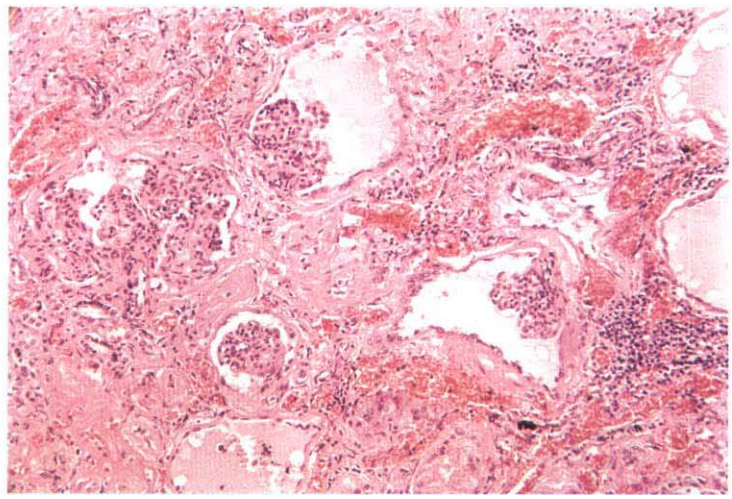
**4–27** Subacute interstitial nephritis
Renal cortex. Heavy interstitial infiltration of lymphocytes and plasma cells. Slight dilation of tubular lumina. This type of lesion is found especially in canine leptospirosis (*Leptospira canicola*). Dog. HE.



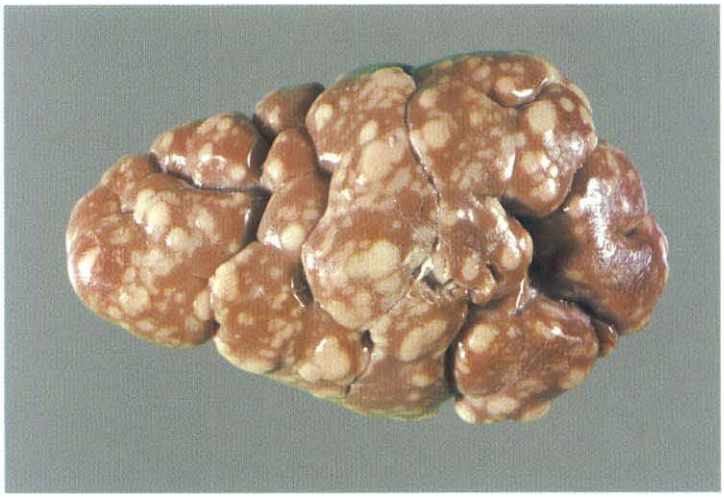
**4–28** Chronic interstitial nephritis
Shrunken, sclerotic left kidney. Cat.



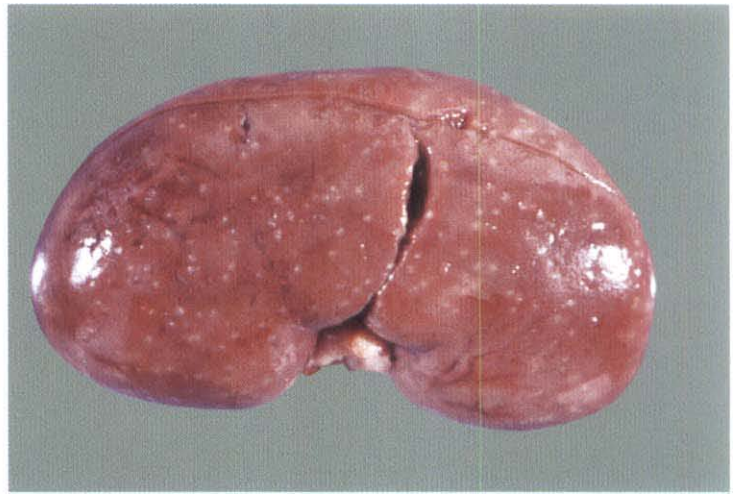
**4–29** Chronic diffuse interstitial nephritis
Renal cut surface. Irregular narrowing of the cortex due to massive loss of nephrons. Obliteration of original cortical and medullary tissue. The cystic dilation of tubules in the medulla may result from cicatrization (tubules with thin epithelial layer), or it represents a compensatory phenomenon (tubules with thick, multilayered epithelium). Dog.



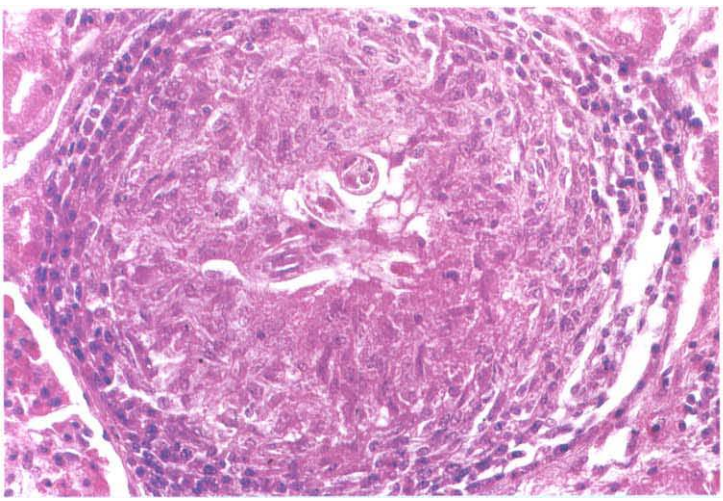
**4–30** Chronic interstitial nephritis
Renal cortex. Almost complete replacement of nephrons by fibrous tissue, which contains random accumulations of mononuclear inflammatory cells. Remnants of tubules, glomeruli situated close together, dilated urinary spaces filled with proteinaceous material, and atrophic glomerular tufts are evident. Adhesions between Bowman's capsule and a tuft of a compensatory-hypertrophied glomerulus (left). Dog. HE.



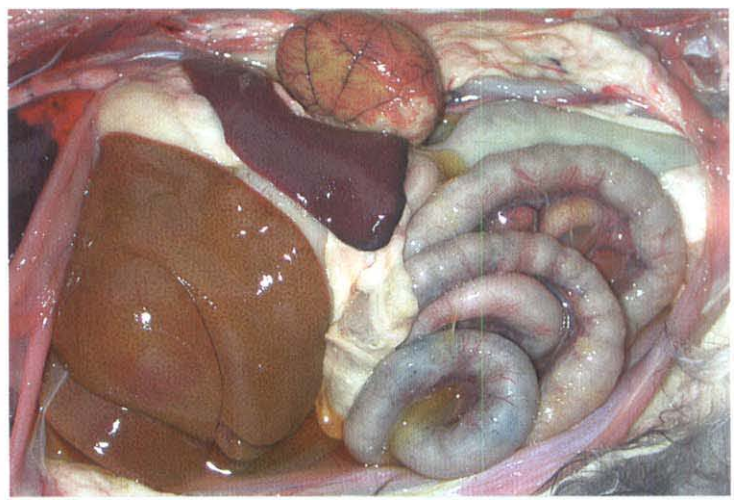
**4–31** Focal interstitial nephritis
Renal surface. Multiple grayish-white prominent nodules (white-spotted kidney) in the renal cortex due to a proliferative inflammation. Histologically characterized by lymphocytic, plasmacellular and histiocytic infiltration, and fibrosis. May be caused by different bacteria e.g. *Escherichia coli, Salmonella, Brucella.* Veal calf.



**4–32** Parasitic nodules
Renal cortex with various small whitish granulomatous foci, a characteristic lesion for parasitic nodules. Dog.

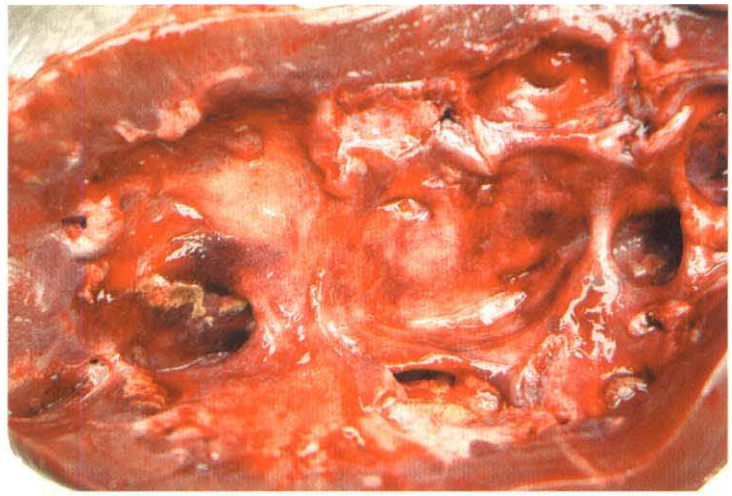


**4–33** Parasitic nodule
A focal granulomatous inflammation surrounding cross-sections of a parasitic larva. The granuloma consists of an inner zone of mainly histiocytes, and an outer zone of plasma cells and lymphocytes with occasional eosinophils. Such a lesion develops as a result of migrating larvae of *Toxocara canis.* Dog, 1 year. HE.

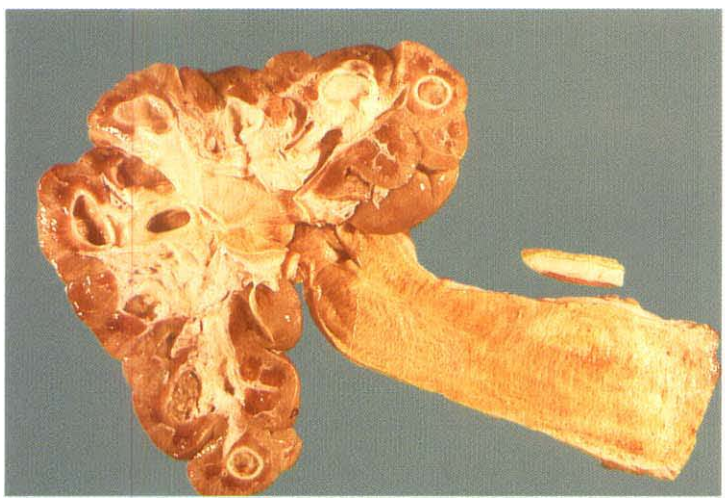


**4–34** Confluent granulomatous lesion
Surface of kidney contains a confluent granulomatous lesion at caudal pole. The abdomen, moreover, contains straw-colored fluid and fibrin strands. Cat with feline infectious peritonitis (FIP).

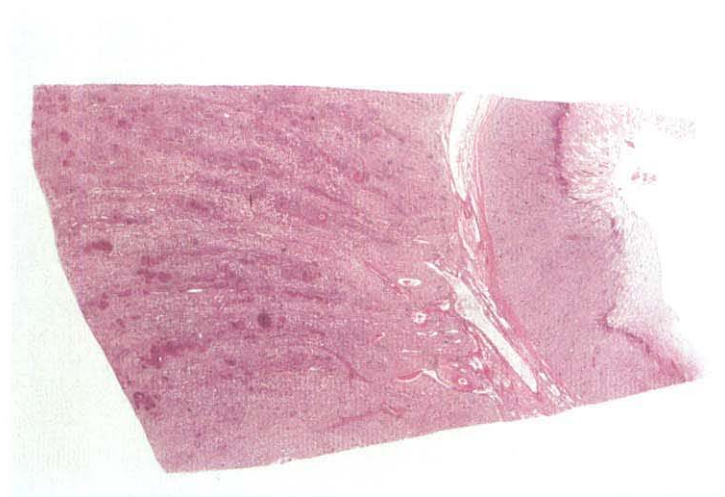
**4–35** Embolic purulent nephritis
Renal surface. Multiple small grayish-yellow prominent foci in renal cortex due to microabscess formation, mainly originating from glomeruli hematogenously infected by pyogenic bacteria. Extension to the medulla and the pelvis frequently occurs. *Arcanobacterium pyogenes*. Cow



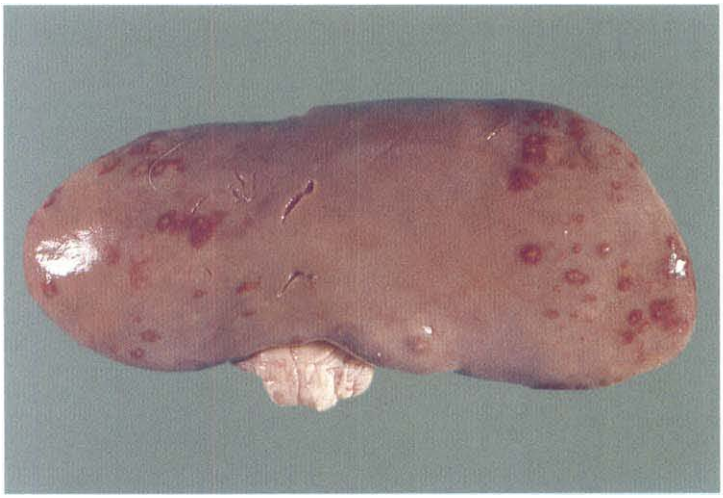
**4–36** Acute pyelonephritis
Cut surface and pelvis of kidney. Multifocal papillary necrosis demarcated by a zone of reactive hyperemia accompanied by purulent pyelitis. The lesions are a sequel of ascending urinary tract infection or descending hematogenous infection. Likely etiology is *Actinobaculum suis*. Pig.



**4–37** Chronic ureteropyelonephritis
Renal cut surface and opened ureter. Enlargement of the ureter due to dilation of the lumen and thickening of the wall. Widening of the renal pelvis (calyces). A rim of reactive connective tissue in the medulla bordering the pelvic cavity. White streaks of scar tissue in cortex and medulla. Cow.

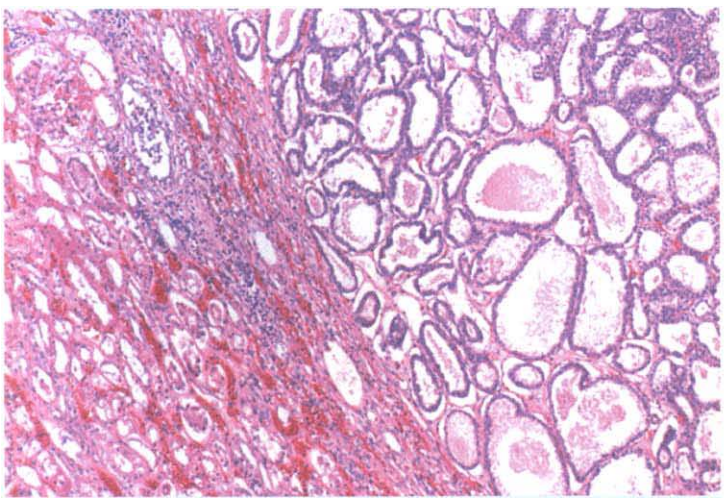


**4–38** Pyelonephritis
Papillary necrosis (right) demarcated by a rim of neutrophils. Multiple round and elongated foci of suppurative inflammation (blue) and areas of fibrosis (pink) in the cortex, suggesting a descending pathogenesis of the necrotizing papillitis. Cow. HE.



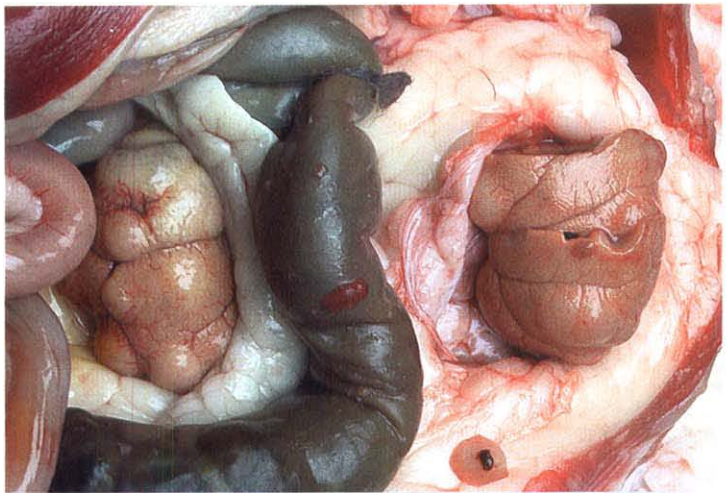
**4-39** Acute purulent nephritis
Renal surface. Predominantly polar localization of multiple raised grayish-yellow foci surrounded by a zone of hyperemia, some depressed chronic inflammatory foci are also present. This typical distribution has been described in experimental reflux pyelonephritis in swine. Pig.

**4-40** Primary renal carcinoma
Renal surface (right) and cut surface (left). A large, bulging tumor mass, replacing the greater part of the kidney. Dog. 16 years.

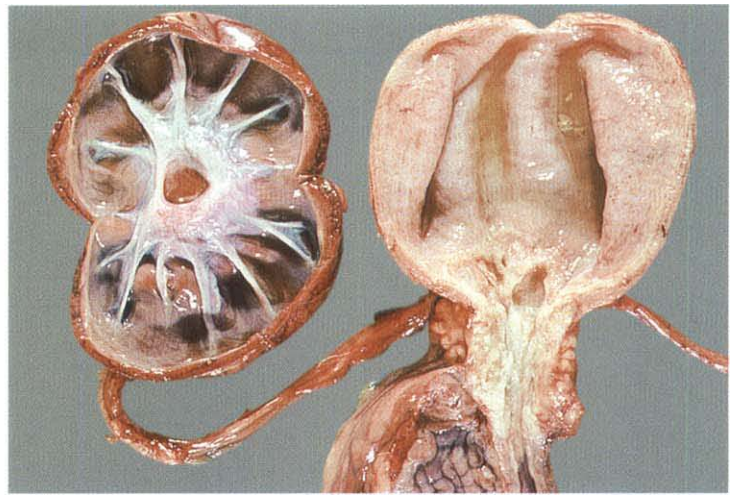


**4-41** Primary renal carcinoma
Histological features of a renal carcinoma. Note dilated tubular structures in tumor (right) with remnant of original kidney tissue (left). Dog. HE.

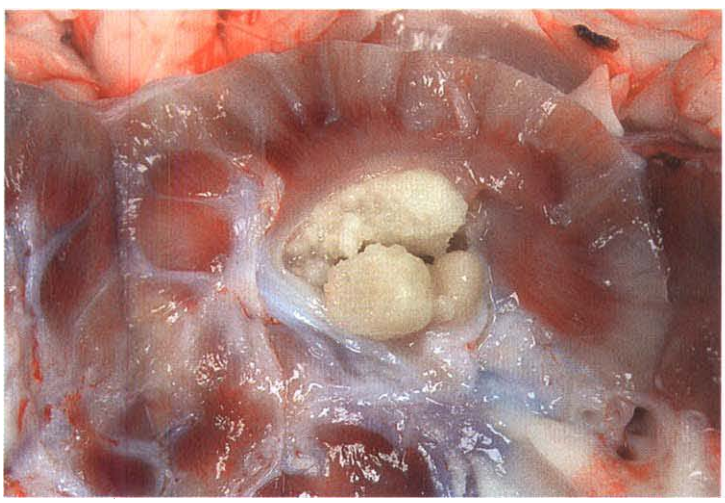
**4-42** Malignant lymphoma
Kidney with several gray-whitish protruding nodules. Sheep.



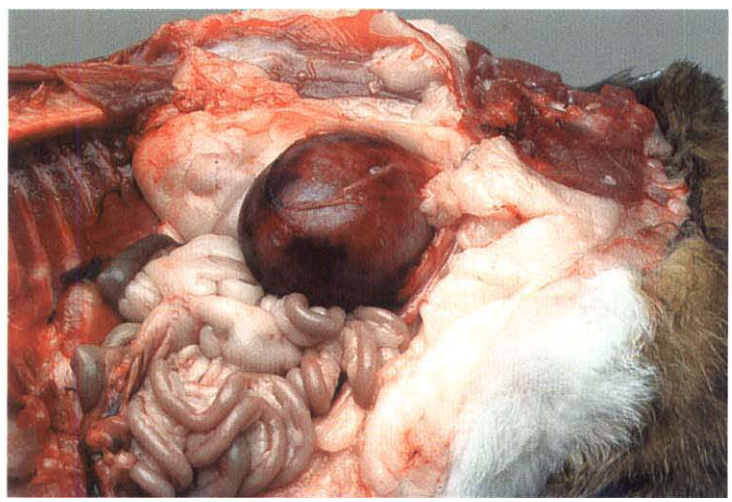
**4–43** Malignant lymphoma
Right (left in figure) and left kidney with protruding grayish nodules. Cat.



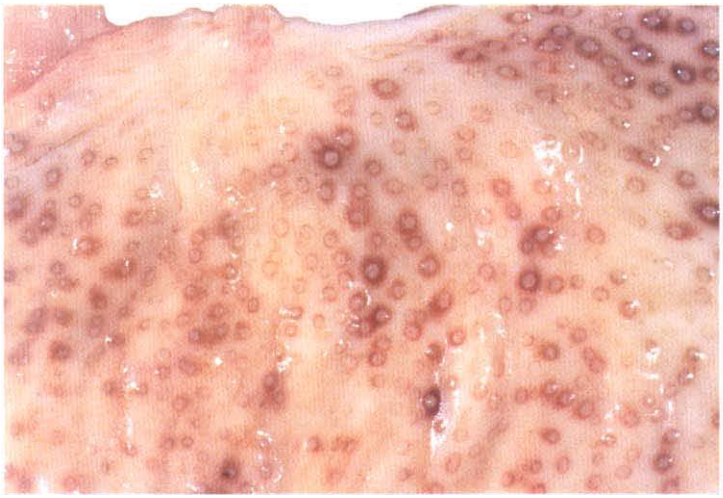
**4–44** Hydronephrosis
Renal cut surface, ureter, and opened urinary bladder. Unilateral dilation of the renal pelvis and ureter (hydroureter) associated with atrophy of renal tissue, caused by impairment of urinary flow due to a transitional cell carcinoma in the neck of the bladder. Muscular hypertrophy of the bladder is present. Dog.



**4–45** Urolithiasis
Cut surface of one kidney. Note large stone in pelvis and some gray colored descending streaks of interstitial nephritis. Cow.

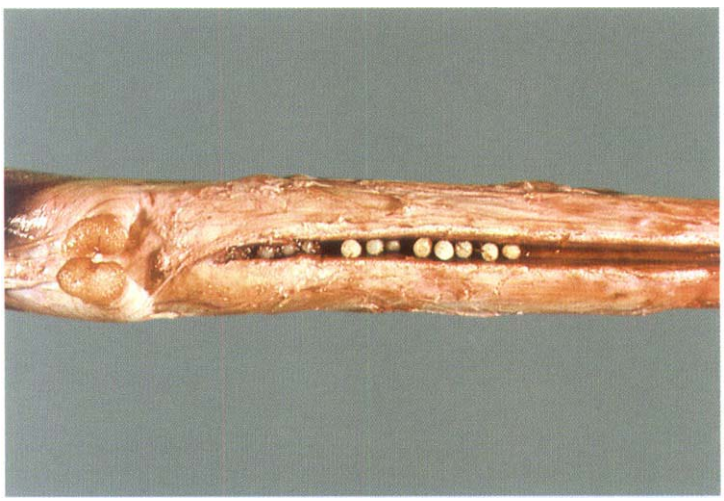


**4–46** Urolithiasis
Distended, acutely hemorrhagic urinary bladder due to urethral obstruction of male cat suffering from feline lower urinary tract disease. Cat.



**4–47** Follicular cystitis
Mucosal surface of urinary bladder. Multiple small gray-white nodules surrounded by a zone of hyperemia. Microscopically consisting of accumulations of lymphocytic cells forming follicular structures. Dog.

**4–48** Hemorrhages in urinary bladder
Mucosal hemorrhages. Classical swine fever. Pig.



**4–49** Urolithiasis
Distal male urethra. A number of small, spherical, smooth, gray-white urinary calculi, causing acute urethritis. Steer.

Chapter 5

# The liver



## THE LIVER

The various disorders of the liver can be differentiated into four categories, each with its own reaction pattern:

- disorders of the biliary system;
- disorders of the circulatory system;
- disorders of the parenchyma; and
- neoplastic disorders.

### *Disorders of the biliary system*

The main *biliary disorders* can be grouped into:

- congenital cystic diseases;
- cholestasis and cholate-stasis; and
- cholangitis.

#### Congenital cystic diseases

*Congenital cystic diseases* are considered to be ductal plate anomalies, which can be divided into three different subtypes:

- congenital hepatic fibrosis, characterized by diffuse porto-portal bridging fibrosis with dilated abnormally structured bile ducts;
- adult polycystic disease, characterized by the presence of multiple grossly recognizable cysts; and
- congenital dilatation of the large and segmental bile ducts (Caroli's disease).

#### Cholestasis and cholate-stasis

*Cholestasis* or bilirubinostasis is morphologically characterized by the presence of bile in the hepatic parenchyma (bile plugs in canaliculi, bile granules in hepatocytes and Kupffer cells) and may have an intrahepatic or extrahepatic origin.

- *Intrahepatic cholestasis* is associated with a wide spectrum of liver diseases; microscopic lesions apart from the cholestasis are related to the primary hepatic disease.
- In *extrahepatic cholestasis* the presence of bile in the parenchyma is evident in acute cases but may be absent in

chronic cases. The characteristic lesions in extrahepatic cholestasis are related to the leakage of bile from the bile ducts into the connective tissue of the portal tracts. This causes an acute (edema, neutrophils) or chronic inflammation (fibrosis, bile duct proliferation, neutrophilic and mononuclear infiltrate) in the stromal tissue of the portal tracts, and leakage of bile from the bile ducts into the periportal parenchyma causing insudation and necrosis of hepatocytes (bile infarct).

*Cholate-stasis* is thought to occur as a result of chronic retention of bile acids in the hepatocytes and is characterized by swollen pale hepatocytes with centrally located copper containing granules, preferentially in the periportal region and often associated with bile duct proliferation.

#### Cholangitis

*Cholangitis* can be differentiated into:

- *neutrophilic cholangitis*, usually resulting from a bacterial ascending infection; it is characterized by the presence of neutrophils in the lumen of the bile ducts possibly extending into the surrounding portal connective tissue and the periportal parenchyma;
- *lymphocytic cholangitis*, a specific disorder in cats, that is characterized by a marked infiltration of lymphocytes in the portal areas often associated with fibrosis and bile duct proliferation;
- *necrotizing and destructive cholangitis*, which may occur as a result of viral or toxic insult or as an idiosyncratic drug reaction, are characterized by necrosis of the biliary epithelium or destruction and loss of bile ducts, respectively; and
- *chronic cholangitis* associated with liver fluke infestation, characterized by marked portal and periductal fibrosis and inflammation within the portal area and exudation into the lumen of the bile duct.

## Disorders of the circulatory system

Circulatory disorders of the liver can be grouped into three major categories:

- congenital portosystemic shunts;
- disorders with outflow disturbances resulting in passive congestion of the liver; and
- disorders associated with deranged inflow of portal blood and portal hypertension.

#### Congenital portosystemic shunts

*Congenital portosystemic shunts* (CPSS) are single large calibre vascular anomalies that directly connect the portal venous system with the systemic venous circulation. Histologically, the liver shows the stereotypical lesions of portal venous hypoperfusion characterized by a hypoplastic or non-recognizable portal vein, and an increased number of arteriolar cross sections because of compensatory arterial flow.

#### Outflow disturbances

Outflow disturbances of the liver result in *passive congestion of the liver* with transudation of plasma and erythrocytes through the liver capsule and fibrin deposition on the liver.

- *Acute passive congestion* is histologically characterized by central–central bridging congestion and subsequent atrophy and loss of centrolobular hepatocytes.
- *Chronic passive congestion* in addition causes perivenous fibrosis extending into the centrolobular parenchyma and adaptive periportal regenerative hyperplasia of hepatocytes.

Outflow disturbances of the liver usually result from cardiac failure or obstruction of the thoracic part of the caudal caval vein.

#### Portal hypertension

*Portal hypertension* may result in the formation of multiple portosystemic collaterals (splenorenal, mesenteric, cardioesophageal) and ascites. It mainly results from chronic primary liver disease, particularly cirrhosis. Portal hypertension may also be the result of primary vascular lesions such as primary hypoplasia of the portal vein or obstruction (thrombosis) of the portal vein.

## Disorders of the parenchyma

*Parenchymal disorders* can be classified as:

- hepatic atrophy and hyperplasia;
- reversible hepatocellular injury and hepatic amyloidosis;
- acute and chronic hepatitis and cirrhosis including hepatocellular apoptosis and necrosis; and
- non-specific reactive hepatitis, hepatic abscesses and granulomas.

#### Hepatic atrophy and hyperplasia

*Hepatic atrophy*, diffuse or focal, results from reduced portal venous flow due to shunting of the portal blood or due to compression of the sinusoids. With extensive atrophy in one part of the liver, the remaining part will show regenerative hyperplasia and increase in size until the original volume of the liver is restored.

#### Reversible hepatocellular injury and hepatic amyloidosis

*Reversible hepatocellular injury* is mainly associated with hydropic degeneration, glycogen storage (steroid induced hepatopathy) and steatosis or lipidosis of the hepatocytes. Depending on the distribution of the lesions the liver is characterized by focal or diffuse swelling, a focal, zonal or diffuse pallor or yellow-tan discoloration, and a friable consistency with increased fragility of the liver. *Hepatic amyloidosis* is characterized by deposition of amyloid in the space of Disse and this also results in hepatic swelling, diffuse or zonal pallor, and increased fragility of the liver.

### Acute and chronic hepatitis and cirrhosis including hepatocellular apoptosis and necrosis

*Hepatocellular apoptosis* and *necrosis*, and the often accompanying *secondary inflammation*, are the hallmarks of hepatitis. They may present as:

- apoptotic or acidophilic bodies, characterized by shrunken intensely acidophilic hepatocytes with a condensed nucleus surrounded by an empty halo;
- focal, confluent and bridging or massive necrosis characterized by swollen coagulated cells with karyopycnosis, karyorrhexis or karyolysis (coagulative necrosis) or by disintegration and loss of hepatocytes with subsequent collapse of the reticulin network (lytic necrosis), sometimes with replacement by erythrocytes and/or infiltration of ceroid laden macrophages; or
- piecemeal necrosis (interface hepatitis) characterized by destruction of the limiting plate, probably by apoptosis, and a mononuclear infiltration at the interface of parenchyma and (newly formed) connective tissue.

In *acute hepatitis*, the inflammatory infiltrate may consist of neutrophils, eosinophils, macrophages, lymphocytes and plasma cells.

*Chronic hepatitis* is characterized by fibrosis, hepatocytic necrosis and a variable mononuclear or mixed inflammatory infiltrate; *cirrhosis* is an endstage of chronic hepatitis characterized by diffuse fibrosis associated with abnormally structured parenchymal hyperplastic nodules. Two morphological categories can be distinguished:

- *macronodular cirrhosis* with small and large nodules of different size; and
- *micronodular cirrhosis* with nodules less than 3 mm (the size of the normal lobule) and of regular size; a specific form of the latter is called lobular dissecting hepatitis.

In both acute and chronic hepatitis it is essential to mention the activity and stage of the disease reflected by the extent of the hepatocytic necrosis and inflammatory reaction, and the presence and extent of fibrosis and nodular transformation of the liver.

### Non-specific reactive hepatitis, hepatic abscesses and granulomas

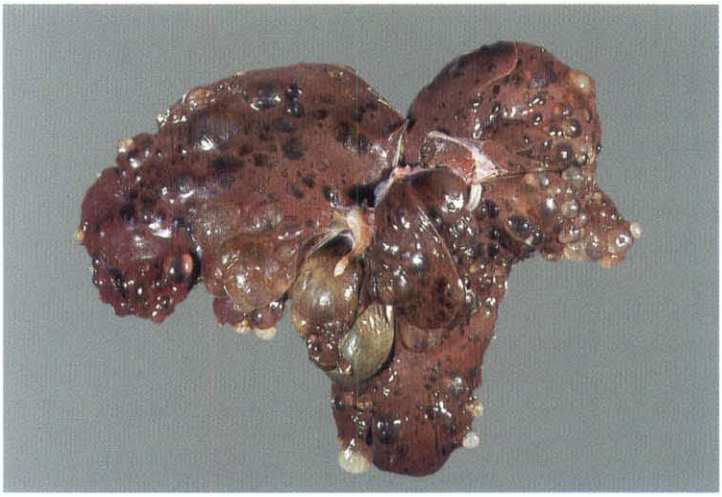
*Non-specific reactive hepatitis* is a morphological entity that represents a non-specific response to a variety of extrahepatic processes or the residual lesions of previous inflammatory intrahepatic processes. The lesion is characterized by a neutrophilic, mixed or mononuclear inflammatory infiltrate, depending on the chronicity, in portal areas and parenchyma without evident hepatocellular apoptosis or necrosis.

*Hepatic abscesses* usually result from bacterial infections, are characterized by intense accumulation and subsequent lysis of neutrophils and are later surrounded by a fibrous capsule.

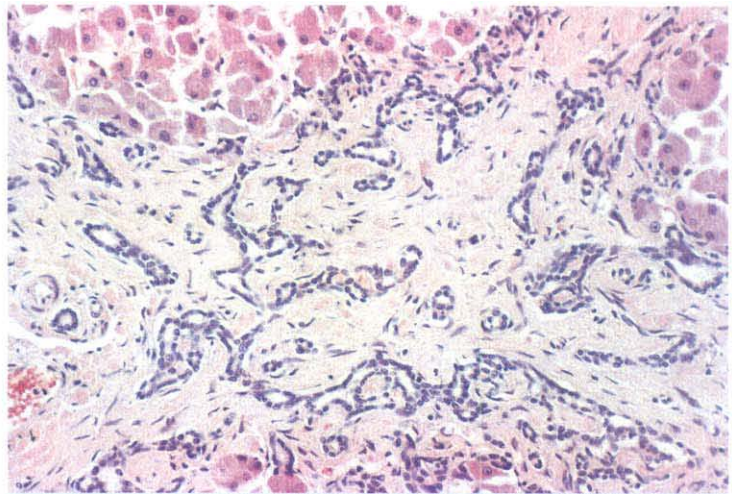
*Hepatic granulomas* may be multifocal or diffuse (granulomatous hepatitis) and present as aggregations of activated macrophages with an epitheloid appearance, mostly accompanied by lymphocytes and plasma cells.

## Neoplasia

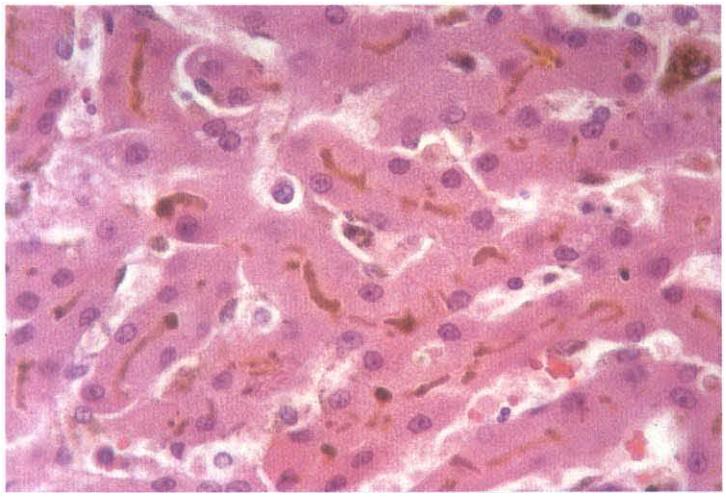
*Primary neoplastic disorders* of the liver are usually of epithelial origin and comprise hepatocellular adenoma and hepatocellular carcinoma, or cholangiocellular adenoma (very rare) and cholangiocellular carcinoma. The malignant tumors often metastasize extensively within the liver along the branches of portal veins and lymph vessels. Nodular hyperplasia occurs particularly in older dogs and cats and often multiple nodules are seen.



**5-1** Congenital cysts
Liver, serosal surface. Multiple cysts in the liver filled with a clear, serous fluid; the cysts are lined by a single layer of flat, cuboidal or columnar biliary epithelium. Dog.

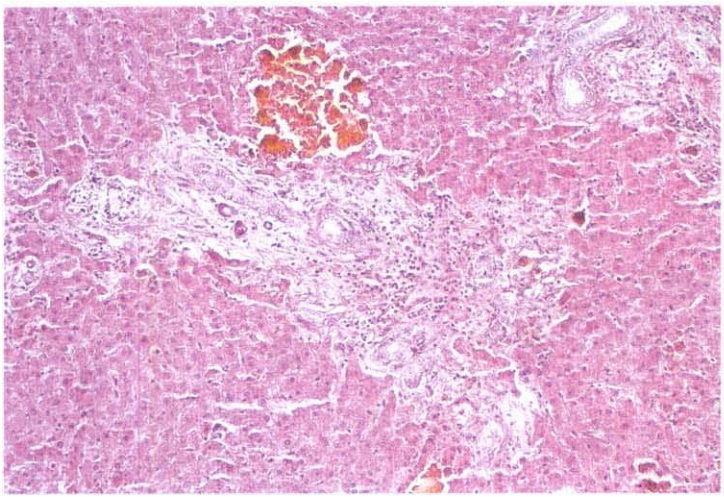


**5-2** Congenital hepatic fibrosis
Marked portoportal bridging fibrosis with irregularly shaped, convoluted and slightly dilated bile ducts. Persian cat. HE.

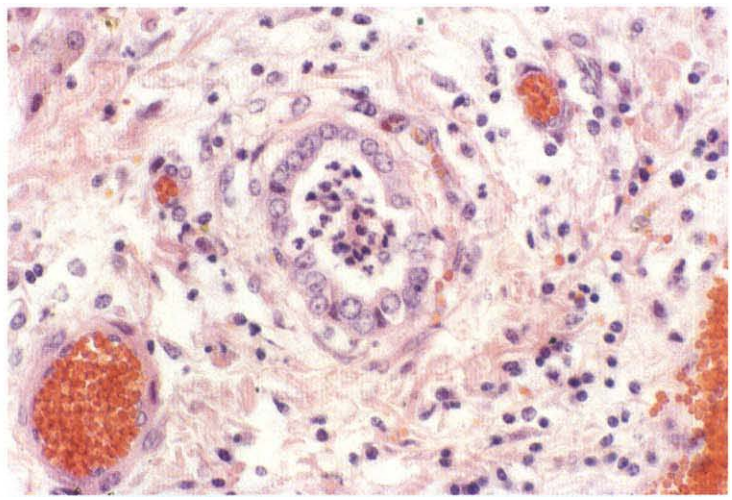


**5-3** Cholestasis
Liver. Bile plugs are present in the canaliculi. Intrahepatic cholestasis. Dog. HE.

**5-4** Extrahepatic cholestasis
A large gall stone is present in the lumen of the opened common bile duct causing obstruction of the normal bile flow. Horse.

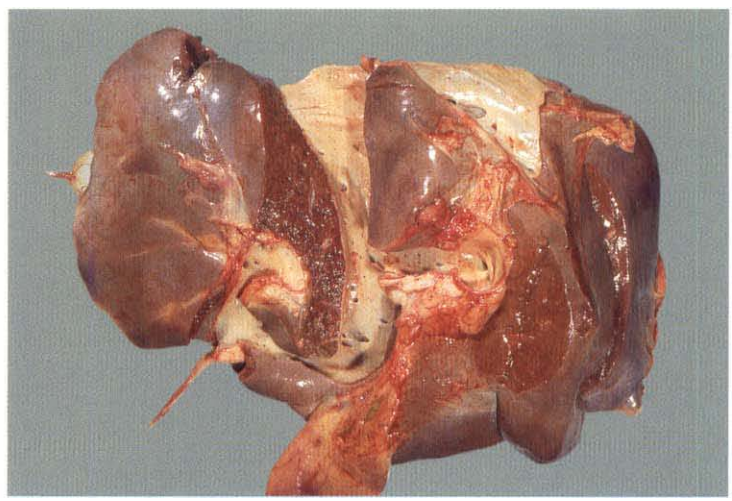


**5-5** Acute extrahepatic cholestasis
Liver. Portal edema and inflammation (neutrophils, mononuclears) and a bile infarct in the adjacent parenchyma. Horse. HE.

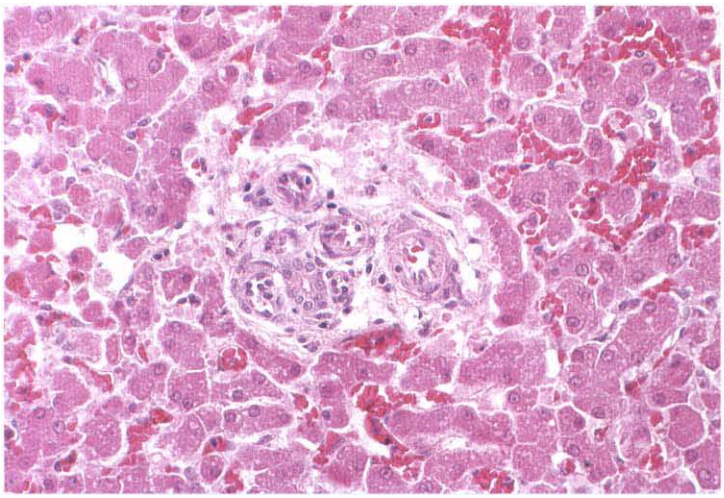


**5-6** Neutrophilic cholangitis
Liver. Neutrophils within epithelial layer and lumen of bile duct with secondary portal inflammation (edema, neutrophils, mononuclear cells). Cat. HE.

**5-7** Chronic cholangitis due to liver fluke infestation
Liver, cut surface. Fibrosis, cholangitis and pericholangitis resulting in thickened fibrotic walls, with debris and adult flukes in the lumen; calcium deposits are often present in the altered bile ducts. *Fasciola hepatica*. Cow.

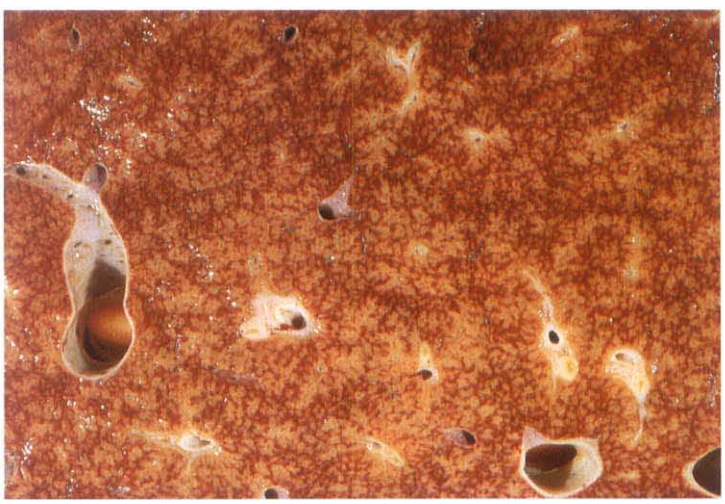


**5-8** Congenital portosystemic shunt, intrahepatic
Liver, abdominal surface. Intrahepatic congenital portosystemic shunt at the site of the original *ductus venosus*. The shunting of portal blood along the persistent *ductus venosus* may result in atrophy of the liver due to diminished portal flow through the liver parenchyma. Calf, 6 months.

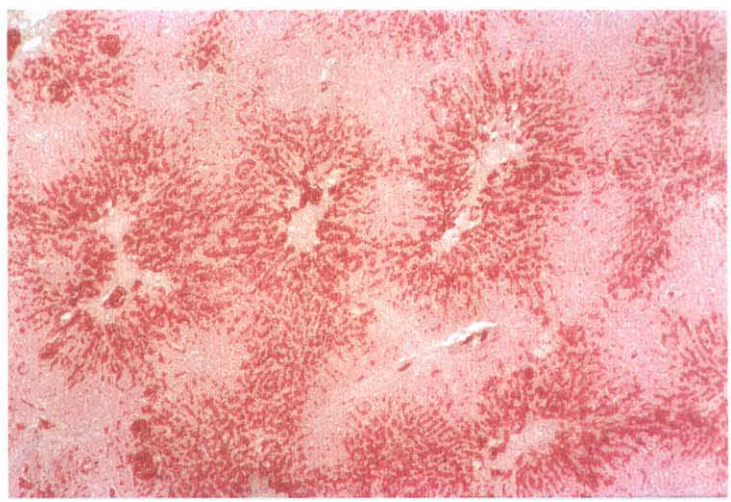


**5-9** Congenital portosystemic shunt
Liver. The portal tract shows the stereotypical lesions of portal venous hypoperfusion characterized by a hypoplastic or non-recognizable portal vein and an increased number of arteriolar cross sections because of compensatory arterial flow. Dog. HE.

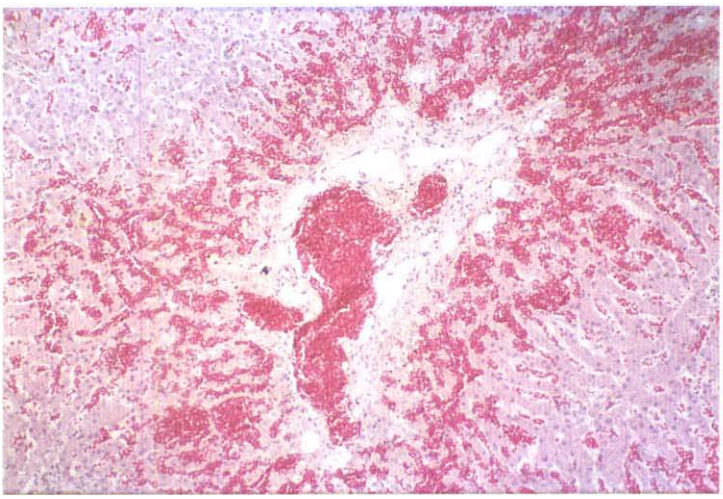
**5-10** Acute passive congestion
Dark swollen congested liver with deposition of fibrin on the serosal surface. Cow.



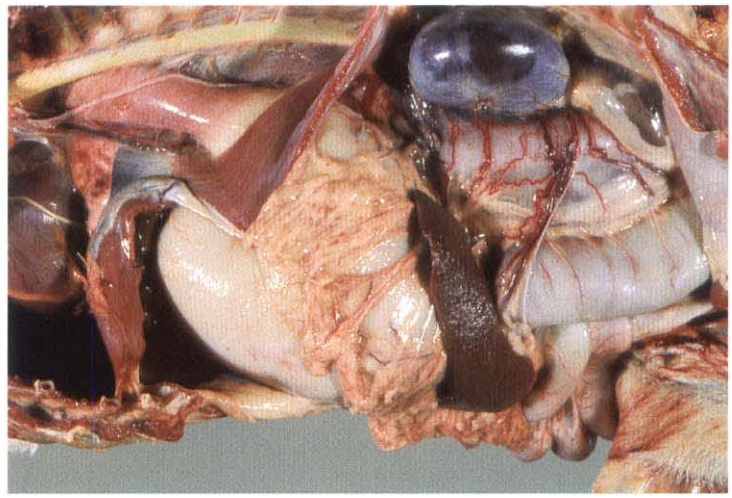
**5-11** Chronic passive congestion
Liver, cut surface. Dark congested liver with pale arborescent areas of hepatocellular regeneration around vessels. The latter results from loss of hepatocytes in the congested centrolobular areas and subsequent hyperplasia of remaining hepatocytes in the periportal areas. Cow.



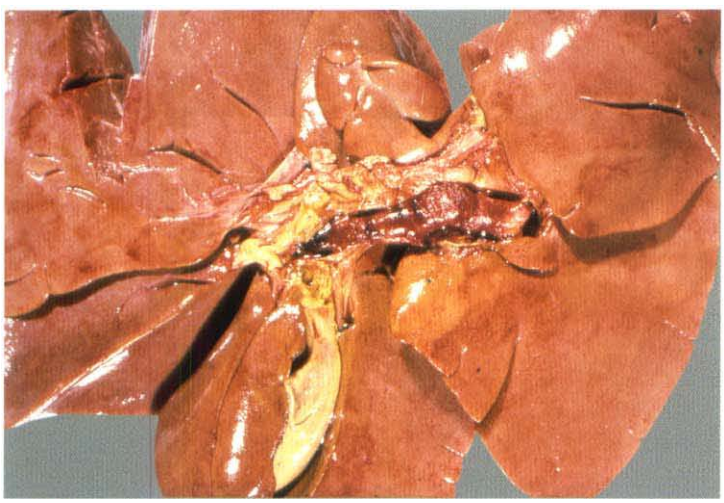
**5-12** Chronic passive congestion
Centrolobular congestion with bridging between adjacent lobules; fibrosis around the central veins. Dog. HE.



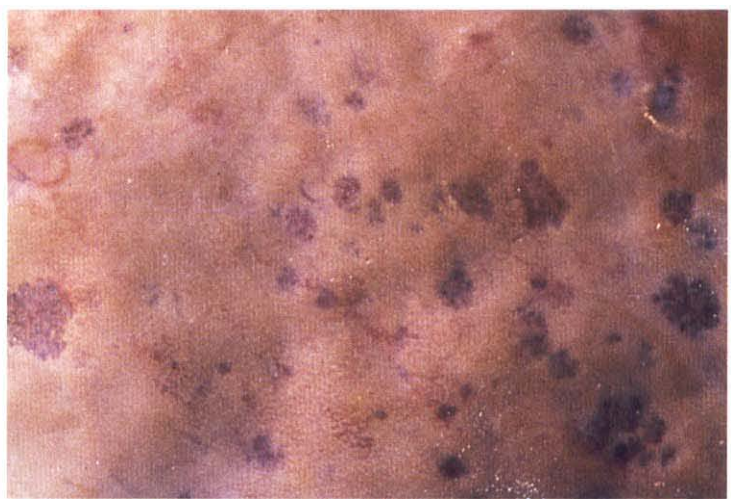
**5-13** Chronic passive congestion
Liver. Fibrosis and dilated lymphatics around the central vein. Congestion of the sinusoids and atrophy of the hepatic cords in the centrolobular area. Hyperplasia of liver cells, evidenced by bilayered hepatic cords, is seen at the periphery of the lobule (lower right). Dog. HE.



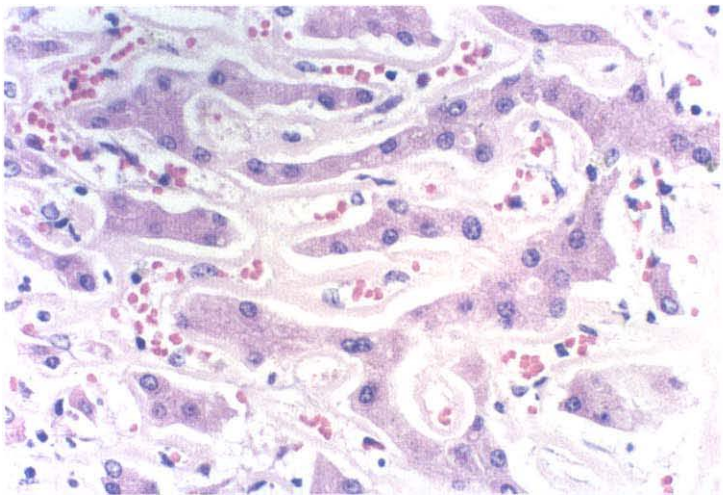
**5-14** Multiple portosystemic collaterals due to portal hypertension
Atrophic cirrhotic liver and marked presence of dilated, tortuous mesenteric, spleno-renal and cardioesophageal collateral portosystemic veins. Dog.



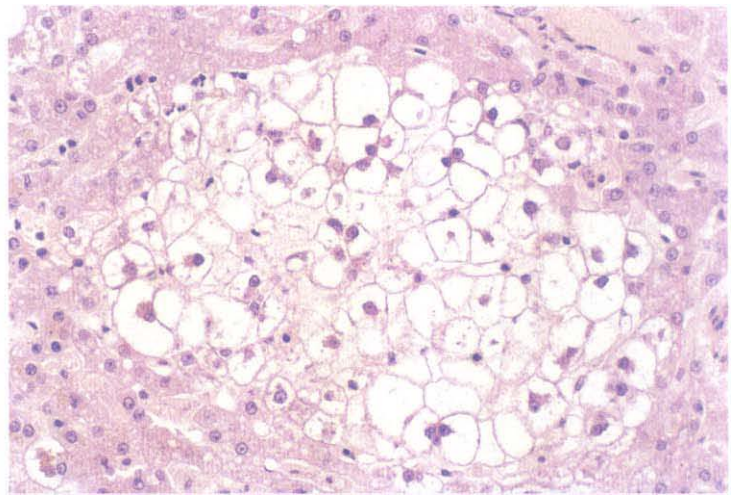
**5-15** Thrombosis of the portal vein
Liver, abdominal surface. A large red thrombus is present in the opened portal vein. Thrombosis of the portal vein is mostly associated with disorders with increased hypercoagulability of the blood or with the nephrotic syndrome. Dog.



**5-16** Teleangiectasis
Liver, serosal surface. Well circumscribed, depressed, dark red areas of varying size consisting of cavernous dilation of groups of sinusoids. Cow.

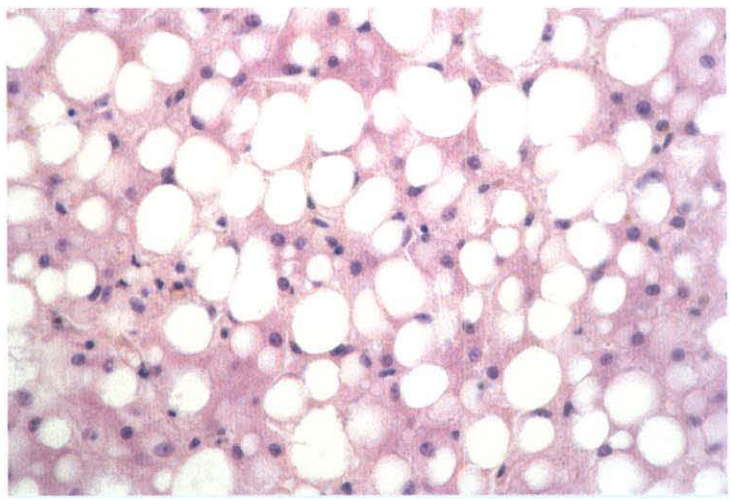


**5-17** Amyloidosis
Liver. Amyloid deposition between the endothelium and the hepatic cords in the space of Disse with secondary atrophy of the liver cell plates. Horse. HE.

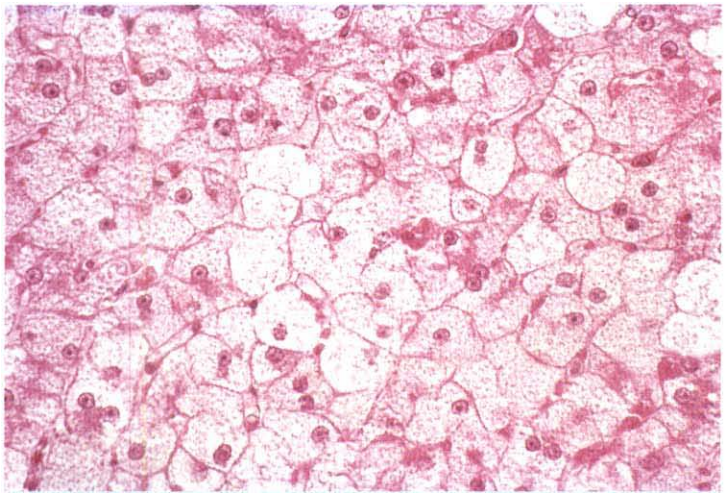


**5-18** Steroid induced hepatopathy
Swelling of the liver cells with reticulation of the cytoplasm, caused by glycogen storage and hydropic degeneration. Hyperadrenocorticism. Dog. HE.

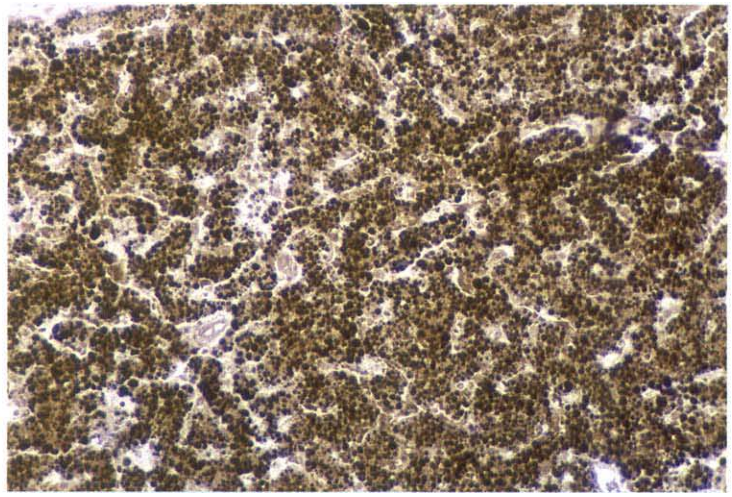
**5-19** Hepatic steatosis and liver rupture
Liver, serosal surface. Diffuse fatty change characterized by an enlarged yellow-colored liver that ruptured in several places due to increased fragility. Hyperlipoproteinemia. Pony.



**5-20** Macrovesicular hepatic steatosis
Liver. Fatty change of liver cells present as single or multiple large fat droplets of varying size, which may displace the nucleus to the periphery of the cells. Hyperlipoproteinemia. Pony. HE.

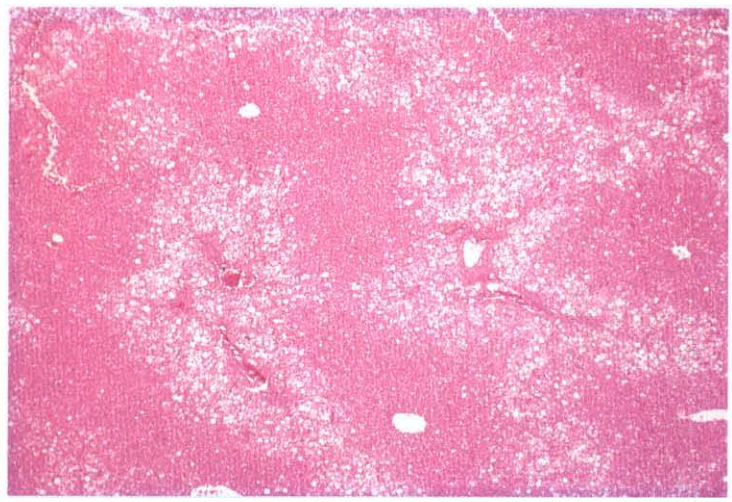


**5-21** Microvesicular hepatic steatosis
Fatty change of liver cells, present as many small fat droplets, uniform in size and smaller than the centrally located nucleus. Diabetes mellitus. Dog. HE.

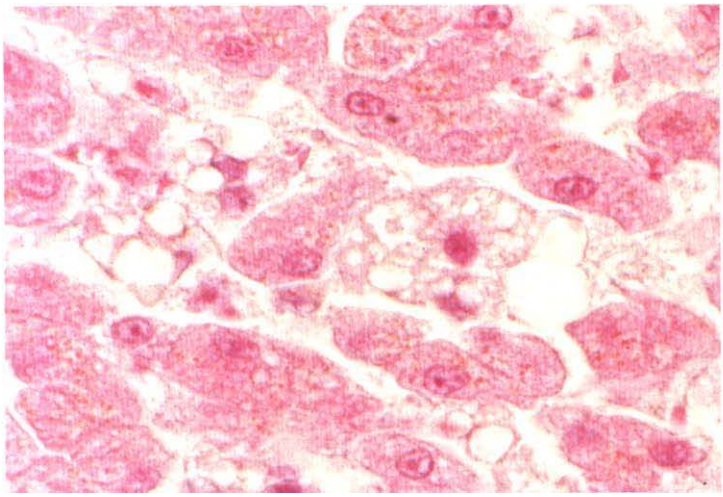


**5-22** Microvesicular hepatic steatosis
Fatty change of liver cells with many small dark-staining fat droplets, uniform in size. Juvenile hypoglycemia. Dog. Yorkshire terrier. OsO4 stain.

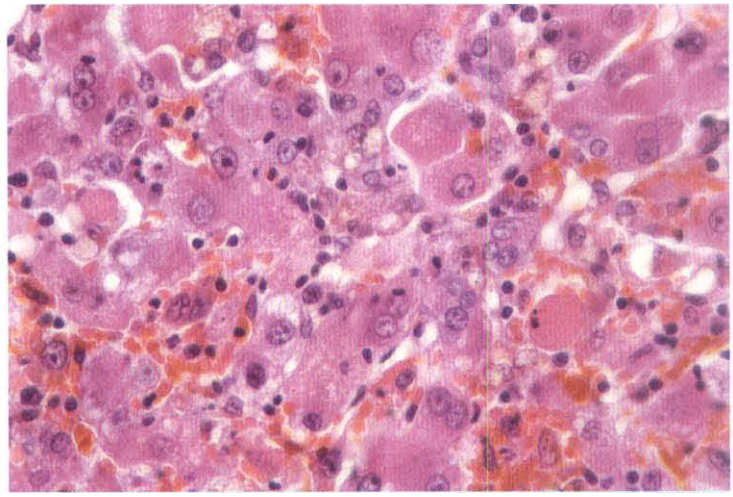
**5-23** Zonal or lobular pattern
Liver, serosal surface. Pale liver with a pronounced zonal or lobular pattern, in this case caused by periacinar or centrolobular hydropic degeneration of the hepatocytes. Goat.



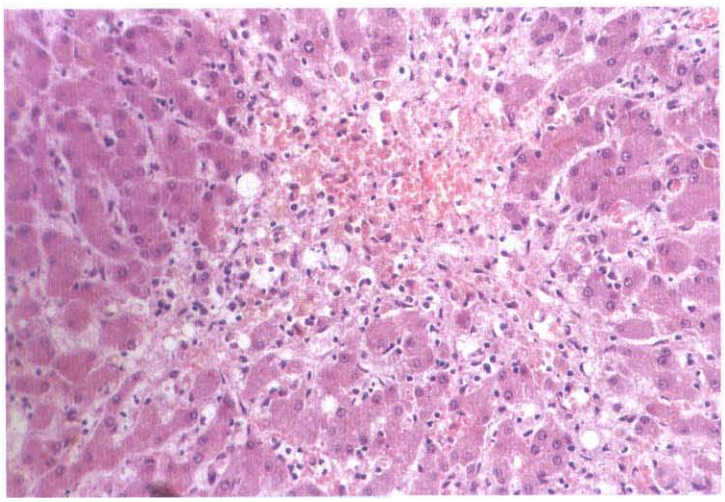
**5-24** Hepatic steatosis with zonal distribution
Liver. Pronounced lobular pattern, in this case caused by the periportal distribution of the steatosis. Ketosis. Sheep. HE.



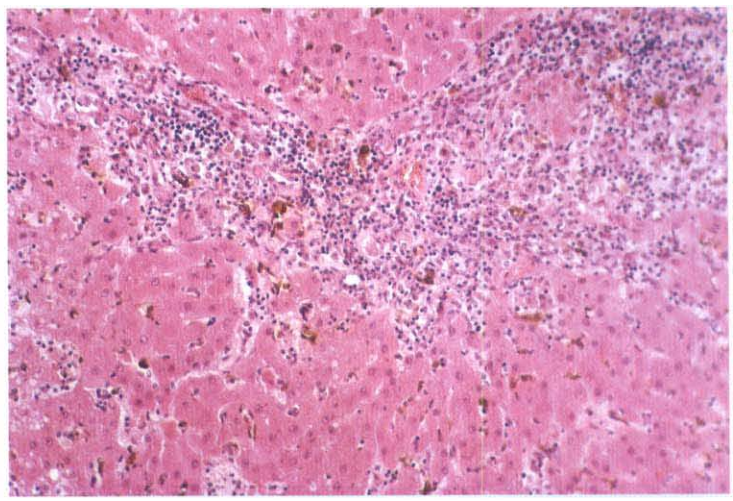
**5-25** Vitamin A intoxication
Liver. Accumulation of small and large fat droplets in fat storing cells, probably hepatic stellate cells (Ito cells), protruding into the lumen of the sinusoids. Cat. HE.



**5-26** Acute hepatitis, apoptotic body
Liver. Acidophilic (apoptotic) bodies and strongly increased cellularity, due to Kupffer cell proliferation, lymphocytes, pigment-laden macrophages and some neutrophils. Dog. HE.



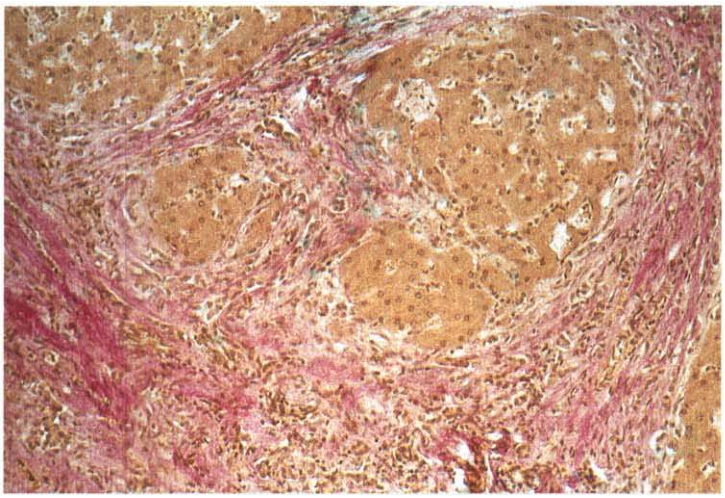
**5-27** Acute hepatitis, confluent necrosis
Liver. Centrolobular confluent necrosis characterized by lysis of liver cells, collapse of the reticulin network and increased cellularity. Dog. HE.



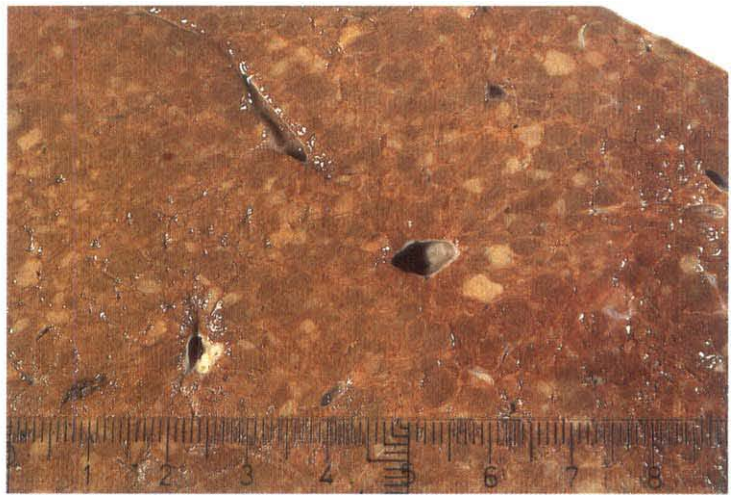
**5-28** Interface hepatitis (piecemeal necrosis)
Liver. Portal inflammation of predominantly mononuclear character, extending over the limiting plate and infiltrating the lobular parenchyma, with necrosis of liver cells. Dog. HE.

**5-29** Massive hepatic necrosis
Liver, cut surface. Degeneration (yellow raised areas) and massive hepatic necrosis (red depressed areas), as may be seen in *hepatosis dietetica* (vit E deficiency). Pig.

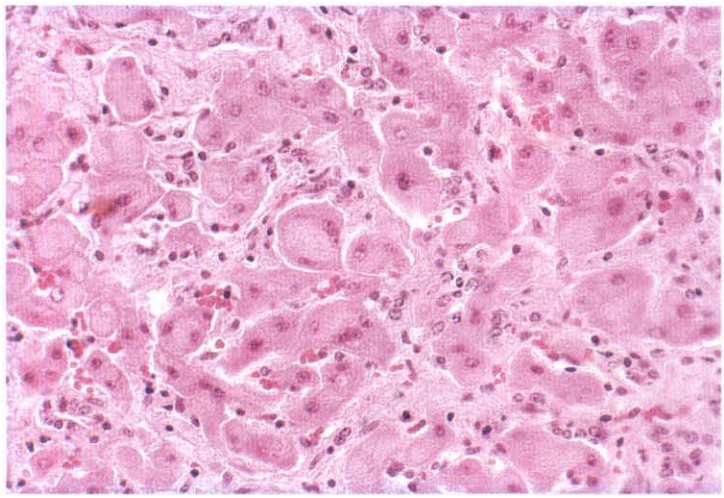
**5-30** Macronodular cirrhosis
Liver, serosal surface. Atrophic liver with pale fibrotic areas and hyperplastic nodules of irregular size most measuring more than 3 mm; fatty changes are often seen within the hyperplastic nodules. Dog.



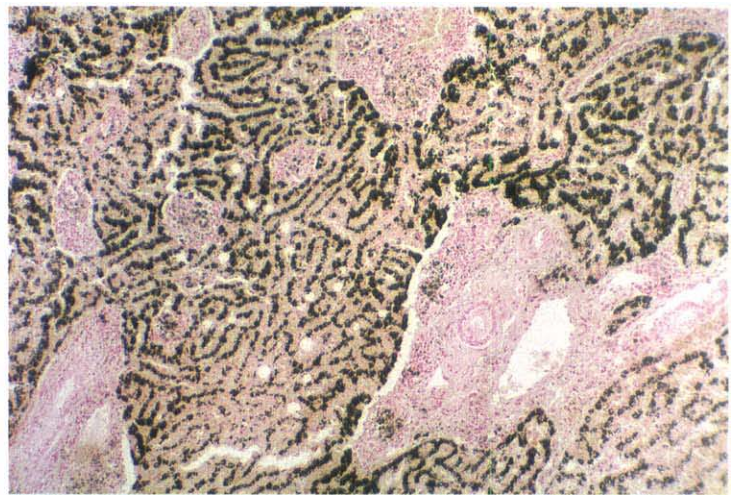
**5-31** Cirrhosis
Liver. Hyperplastic parenchymal nodules separated by fibrous bands, with distortion of the normal liver architecture; moderate infiltration of mononuclear cells. Dog. Van Gieson.



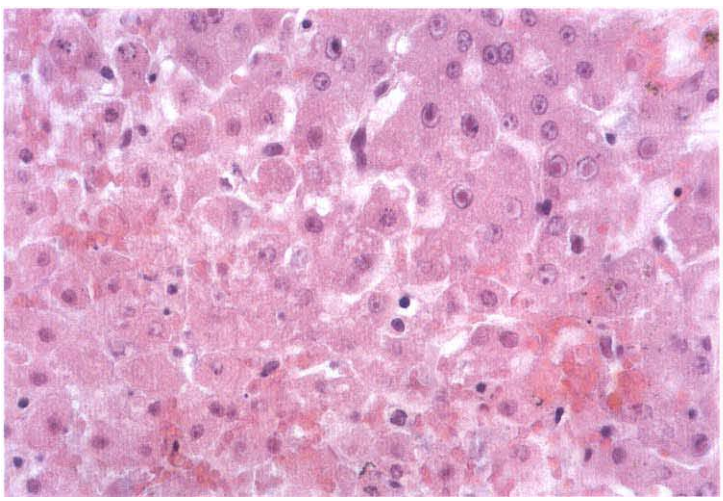
**5-32** Micronodular cirrhosis
Liver, cut surface. The liver is enlarged; hyperplastic nodules are of regular size, and most are 3 mm or less in diameter. The variable rusty color of the liver is caused by the varying Fe–content. Hemochromatosis. Cow.



**5-33** Lobular dissecting hepatitis
Fibrous dissection of the liver parenchyma into individual and small groups of liver cells; also multinucleated syncytial liver cells may be present. Lobular dissecting hepatitis particularly occurs in neonatal and juvenile animals. Calf. HE.

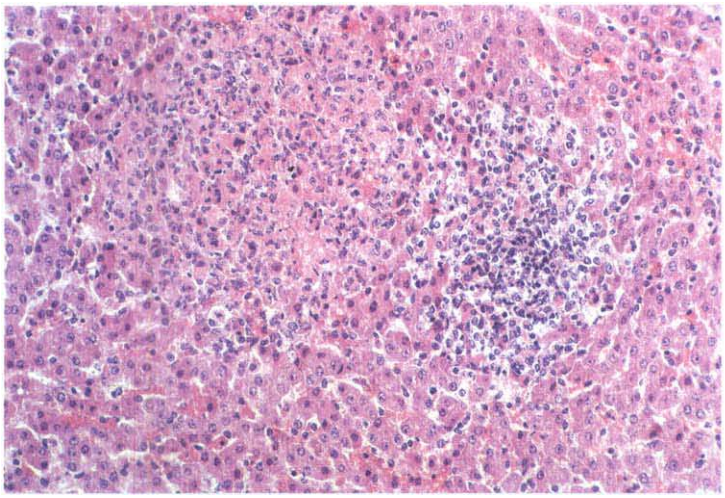


**5-34** Inherited copper toxicosis
Extreme deposition of copper (dark green) in the liver, complicated by chronic hepatitis. The copper is present in the hepatic cords as well as in macrophages within the pale areas with fibrosis and, or inflammation. Dog. Bedlington terrier. Rubeanic acid stain for copper.



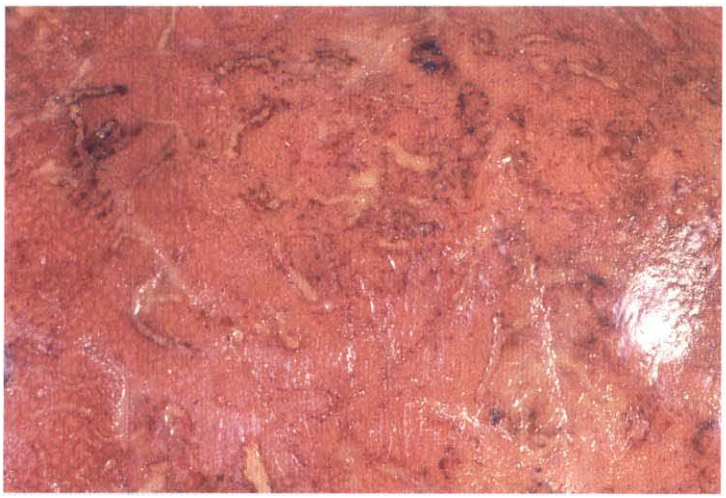
**5-35** Contagious canine hepatitis
Necrosis of liver parenchyma (lower left) and large amphophilic intranuclear adenoviral inclusion bodies in the intact hepatocytes. Dog. HE.

**5-36** Multifocal miliary necrosis
Liver. Randomly distributed miliary foci (<1 mm) of necrosis and inflammation. Abortigenic equine herpes 1. Foal.



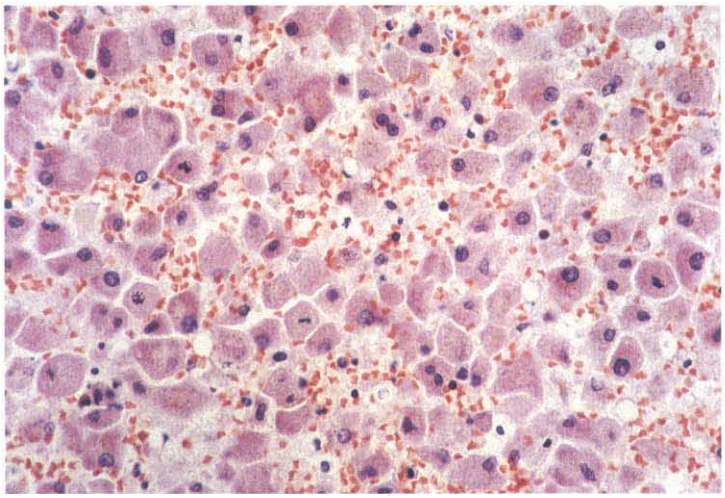
**5–37** Acute hepatitis, focal necrosis
Liver. Multifocal necrosis with moderate (left) or strong (right) proliferation of Kupffer cells and infiltration by phagocytes, as seen in several septicemic infections. Salmonellosis. Calf. HE.

**5–38** Necrobacillosis
Liver, cut surface. Acute coagulative necrosis, caused by *Fusobacterium necrophorum*, surrounded by a zone of hyperemia. Cow.

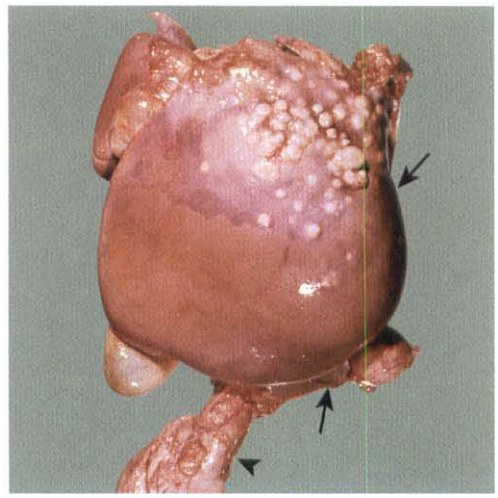


**5–39** Acute fascioliasis
Liver, serosal surface. Tracks of migratory flukes in acute *Fasciola hepatica* infestation. Sheep.

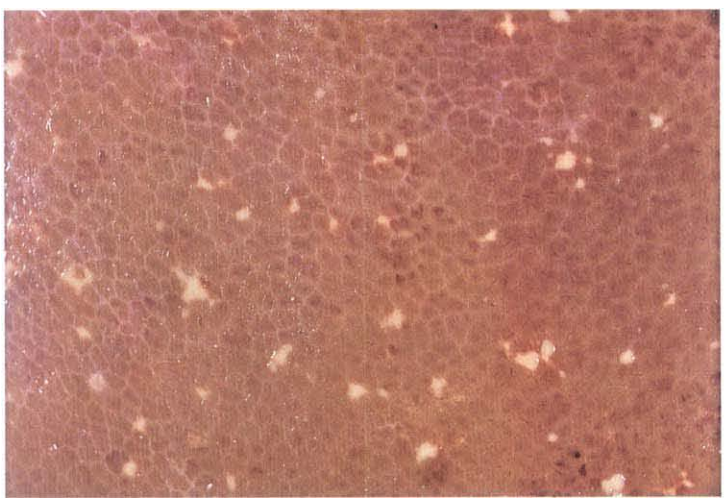
**5–40** Leptospirosis
Jaundice. Hemorrhages in the lungs and in the serosa of the stomach. The liver is usually grossly normal, but may show some zonal degeneration. *Leptospira icterohaemorrhagica*. Dog.



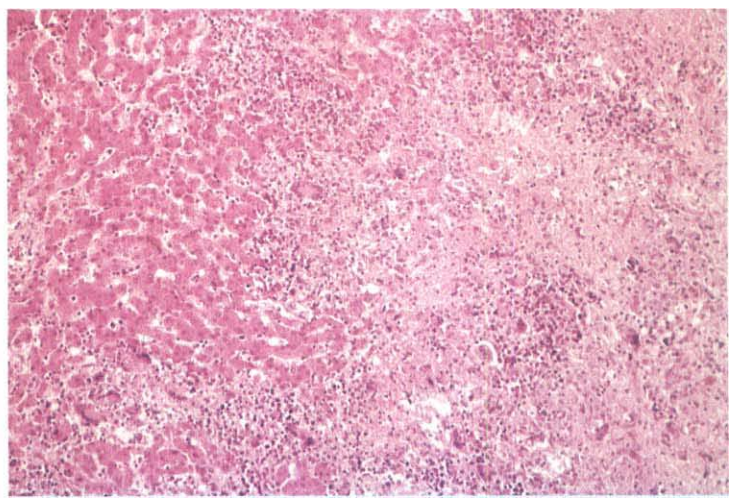
**5-41** Leptospirosis
Liver. Mitotic figures and double-nucleated hepatocytes. The characteristic liver cell dissociation is markedly exaggerated by postmortem changes, since in liver biopsies dissociation mostly is not recognized. *Leptospira icterohaemorrhagica*. Dog. HE.



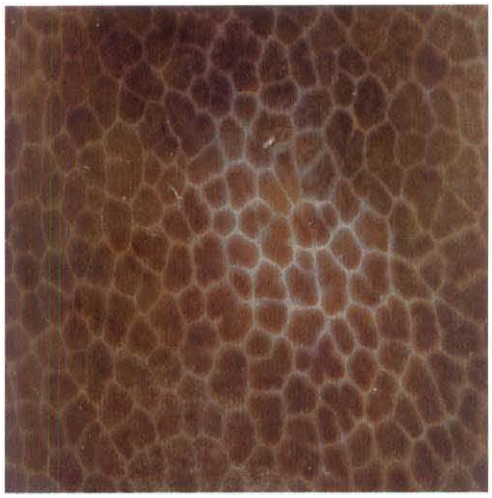
**5-42** Hepatic abscesses and omphalophlebitis
Liver, serosal surface, diaphragmatic aspect. Metastatic hepatic abscesses originating from an omphalophlebitis (arrowhead) and severe atrophy of the left side of the liver (arrows) due to occlusion of the left branch of the portal vein associated with the ascending omphalophlebitis. Calf.



**5-43** Avian tuberculosis
Liver, serosal surface. Multiple gray, hyaline tubercles spreading along the interlobular septa and infiltrating the lobules. Avian tuberculosis (*Mycobacterium avium*). Pig.

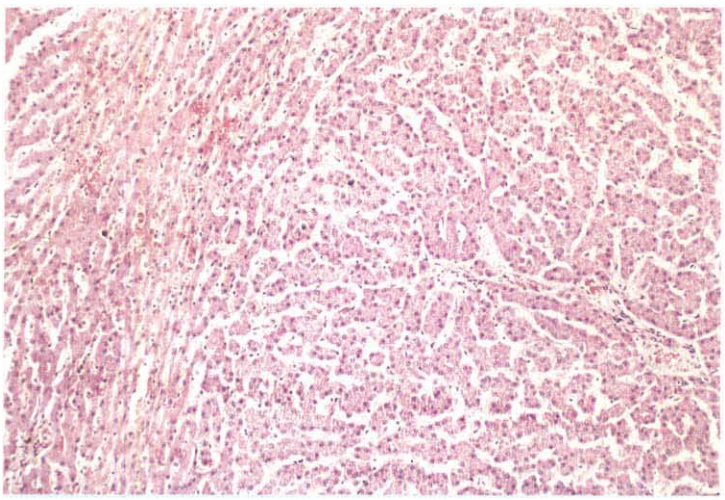


**5-44** Avian tuberculosis
Proliferative interstitial hepatitis with Langhans' cells and, very limited, caseous necrosis. The inflammatory process infiltrates into the lobular parenchyma. Avian tuberculosis (*Mycobacterium avium*). Pig. HE.

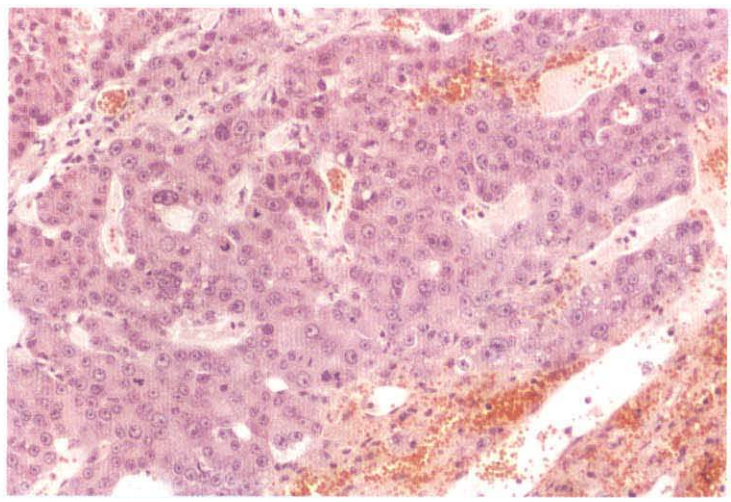


**5-45** White spot, granulomatous type
Liver, serosal surface. Focal chronic interstitial hepatitis, with a network of thickened interlobular septa, due to migrating larvae. Ascariasis (*Ascaris suum*). Pig.

**5-46** Nodular hyperplasia
Liver, serosal surface. Nodular hyperplasia of liver parenchyma with fatty change, as is commonly observed in old dogs. Dog.



**5-47** Nodular hyperplasia
Liver. Well demarcated non-encapsulated hyperplastic nodule consisting of bilayered hepatic cords, and slight compression of the adjacent parenchyma. Dog. HE.



**5-48** Hepatocellular carcinoma
Liver. Broad multilayered trabeculae of neoplastic liver cells separated by thin bands of capillary stroma and sinusoids. Malignancy is determined by the extent of cellular pleiomorphism and the number of mitotic figures. Cat. HE.

Chapter 6

# The alimentary tract

# THE ALIMENTARY TRACT

The alimentary tract includes the oral cavity, salivary glands, pharynx, esophagus, forestomachs, stomach, and small and large intestine.

The most common lesions consist of:

- congenital anomalies (for example cleft palate, polydontia, small intestinal membrane atresia, atresia ani);
- displacement (for example gastric dilation/volvulus syndrome, hernia diaphragmatica, volvulus, intussusception);
- luminal changes (for example intestinal diverticulum, rectal stricture);
- circulatory disturbances (for example gastric edema, infarction, protein losing enteropathy);
- cellular pathology (for example enamel hypoplasia, dental caries, parakeratotic hyperkeratosis);
- inflammation; and
- neoplasia.

The most important lesions are associated with inflammatory processes and neoplasia.

## Inflammatory processes

The inflammatory processes, which may cause superficial or deep lesions, are found throughout the alimentary tract and are classified as catarrhal, purulent, phlegmonous, erosive, ulcerative, fibrinous, necrotizing, proliferative and granulomatous.

The inflammation of the cutaneous mucous membranes may also result in papular and vesicular lesions.

In addition, there are some special general characteristics related to inflammation of the gastric, small and large intestinal mucosa.

### *Gastritis*

In *proliferative gastritis* the thickness of the mucosa may be reduced (atrophy) or increased (hypertrophy) due to changes in the length of the gastric pits and/or glands. Proliferative gastritis without changes in the mucosal thickness may be *superficial, diffuse* or *follicular. Follicular gastritis* may erroneously suggest lymphoma. In the fundic area of the stomach the differentiation of the mucinous neck cells into parietal and chief cells can be changed into mucinous cells; this process is called *pseudopyloric metaplasia.*

### *Enteritis*

With *inflammation of the small intestine* the mucosal thickness may be reduced (atrophy) or increased (hypertrophy) due to changes in the length of crypts and villi. Further, in case of *villus atrophy* this may be characterized as *hyporegenerative* (primary alteration of crypt epithelium resulting in shortening of villi) or *hyperregenerative* (primary alteration of villus epithelium with shortening of villi and adaptive lengthening of crypts). Villus atrophy can also be induced by food hypersensitivity or toxic agents without (evident) inflammation. The differentiation from enteroblasts into enterocytes or goblet cells may change into predominantly goblet cells, a process called *goblet cell hyperplasia.*

### *Typhlitis, colitis and proctitis*

The proliferative *inflammation of the large intestine* without changes of the mucosal thickness may be classified as *superficial, diffuse* or *follicular*; with changes of the mucosal thickness as *hypertrophic* or *atrophic.* The follicular inflammation may resemble lymphoma, especially in biopsies.

Depending on the type and the severity of the gastroenteritis the *mucosal barrier* (mucus, epithelial and lymphoreticular layers) may be altered functionally.

## Neoplasia

The *neoplasms* in the alimentary tract can be classified according to their cells or tissues of origin, namely the squamous or glandular epithelium, melanocytes, soft tissues, hemopoietic cells, salivary glands, odontogenic tissues, neuroendocrine cells (carcinoid tumors) and mesothelium.

Gastro-intestinal tumors may result in luminal occlusion, ulceration and perforation. Carcinoid tumors may induce *paraneoplastic signs* by secretion of (ectopic) polypeptide hormones.

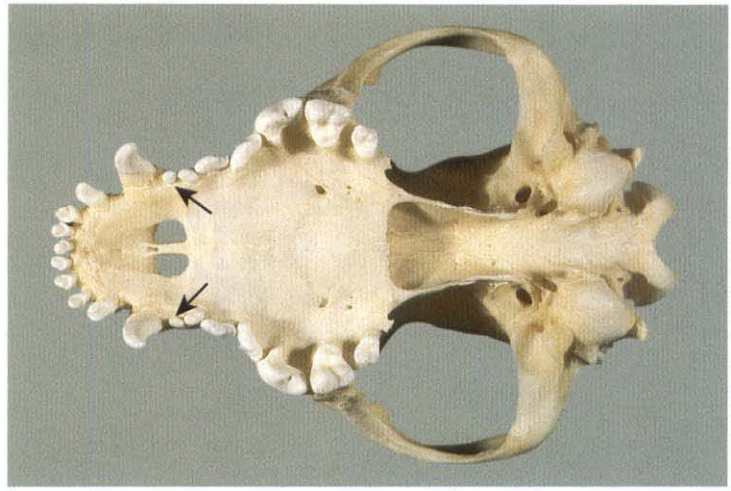
## Maldigestion, malabsorption and malsecretion

Morphological alterations of the alimentary tract may interfere with the functions of:

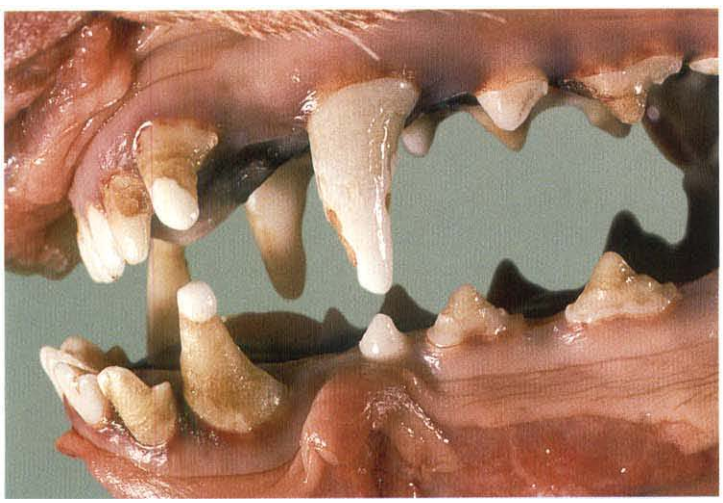
- prehension, taste and mastication (oral cavity and pharynx);
- transport and regurgitation (ruminants) of food (esophagus);
- fermentation (forestomachs);
- motility, secretion and digestion (stomach);
- motility, secretion, digestion and absorption (small intestine); and
- motility, microbial fermentation (in strongly developed intestinal compartments, as in large intestines of horses), secretion and absorption (large intestine).

So, functionally these alterations result in *maldigestion, malabsorption* and *malsecretion.* These basic functional disorders may be evidenced by the main clinical symptoms of *regurgitation, vomiting, diarrhea* or *constipation.*

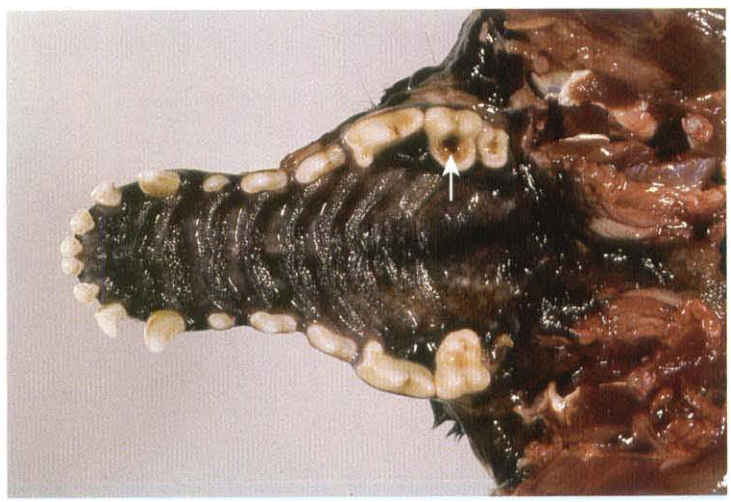
**6-1** Cleft palate (palatoschisis)
Head, view into the opened mouth. Inadequate growth of the palatine shelves resulting in communication between the oral and nasal cavities. Kitten.



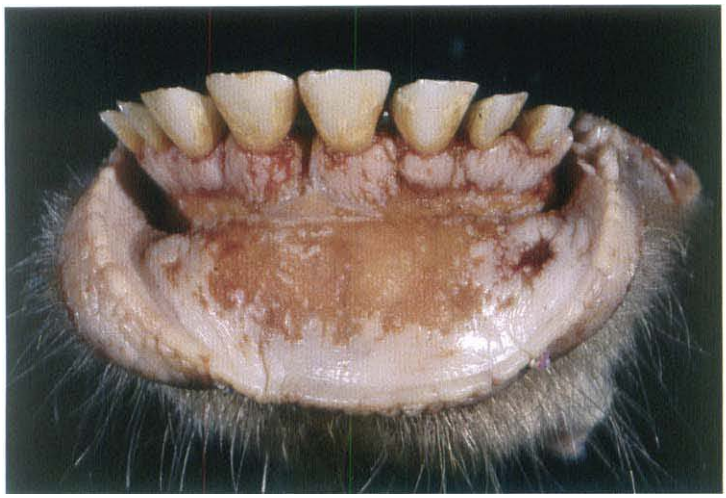
**6-2** Polydontia
Supranumary incisor teeth (8 instead of 6 teeth), and double left and right first premolar (arrows) in the maxilla. Boxer. Dog.



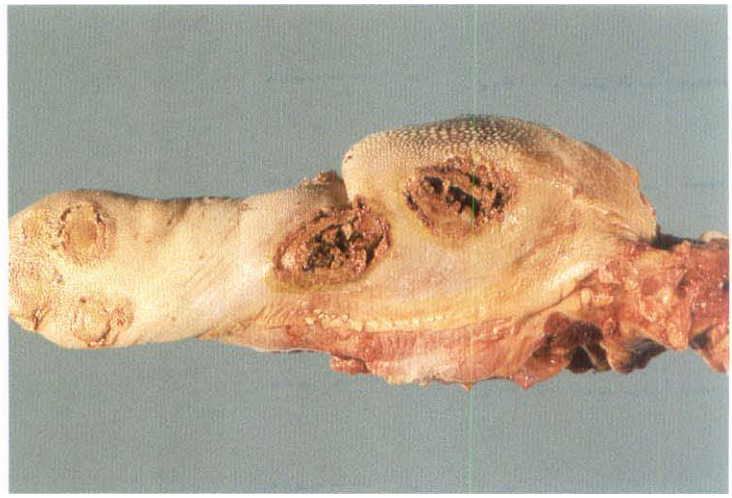
**6-3** Enamel hypoplasia
Enamel defects in the permanent incisors and premolars, caused by degenerative changes of the ameloblasts. Distemper. Dog.



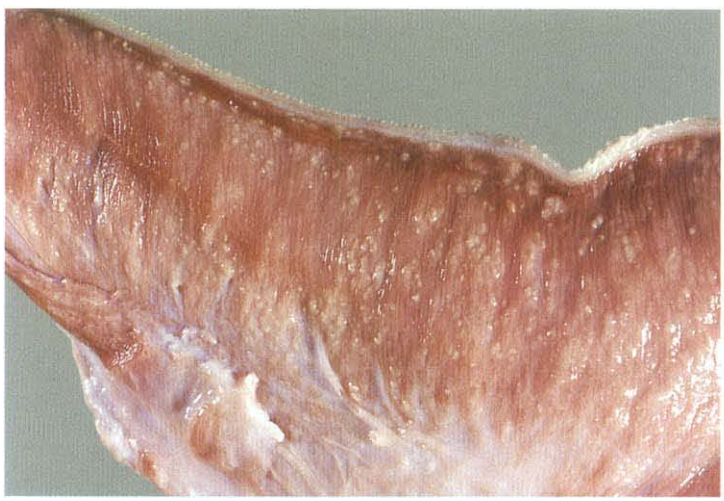
**6-4** Dental caries
Caries media of the first left maxillary molar, with destructive decalcification of the enamel and the dentine, accompanied with a brown-black discoloration of the centre of the tooth (arrow). Dog.



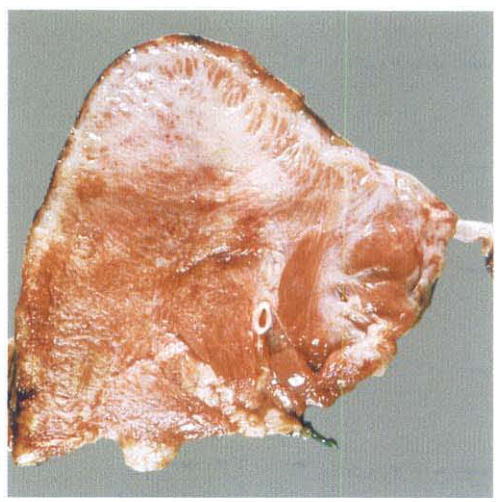
**6-5** Acute stomatitis
Superficial epithelial defects of the oral mucosa (erosion) and deeper lesions which extend into the substantia propria (ulceration), both with acute inflammation in the underlying propria. Mucosal disease-Bovine Virus Diarrhea (MD/BVD). Cow.



**6-6** Necrobacillosis
Large, well-demarcated, yellowish-gray, dry areas of coagulation necrosis in the tongue. The necrotic areas are locally separated from the surrounding viable tissue (sequestration). *Fusobacterium necrophorum.* Calf.



**6-7** Actinobacillosis
Tongue, sagittal section. Small bulging white spots: actinobacillary granulomas. Histologically characterized by a colony of bacteria surrounded by dense eosinophilic material with clubs, and more peripherally by neutrophils, mononuclear cells and connective tissue (see Fig. 1-22). *Actinobacillus lignieresii.* Cow.

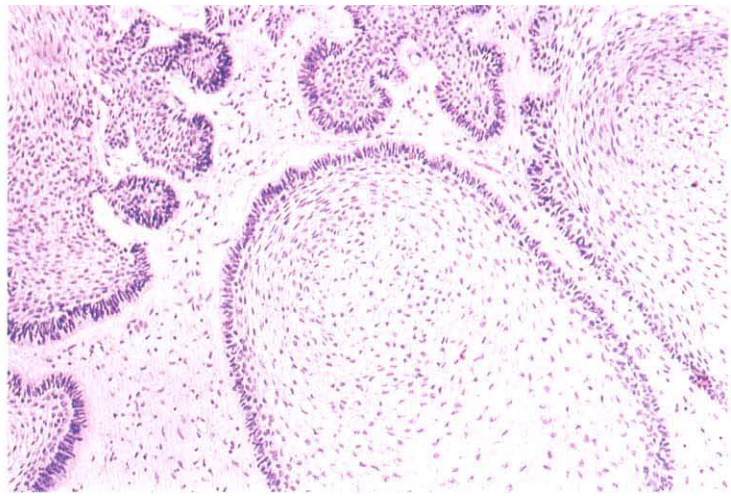


**6-8** Actinobacillosis
Tongue, cross section. Diffuse sclerosing actinobacillosis (also called 'wooden tongue'). The tongue is enlarged, white, and firm as a result of a severe proliferation of connective tissue which replaces the muscular tissue. *Actinobacillus lignieresii.* Cow.

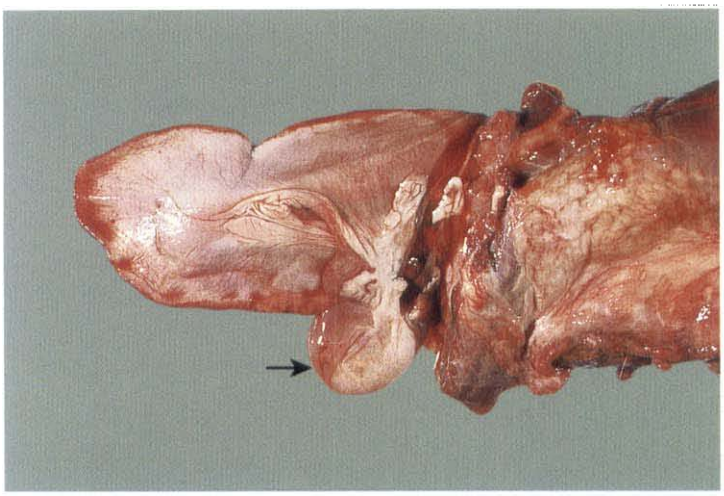
**6-9** Fibrinous periodontitis
Hyperemia and fibrinous exudate on the surface of the gingival mucosa, especially around the incisor teeth. Destruction of the periodontal membrane. Cow.

**6-10** Fibromatous epulides
Multiple benign tumorous masses on the gingival mucosa. Histologically composed of periodontal ligament-type stroma and often cords of (odontogenic) epithelium, dentin, cementum and bone. Frequently together with hyperplasia and proliferative inflammatory lesions of the gingiva. Sometimes, similar masses prove to be peripheral ameloblastoma, canine acanthomatous ameloblastoma (formerly: acanthomatous epulis), other odontogenic tumors or melanomas, most of them with local destructive growth. Brachycephalic dog.

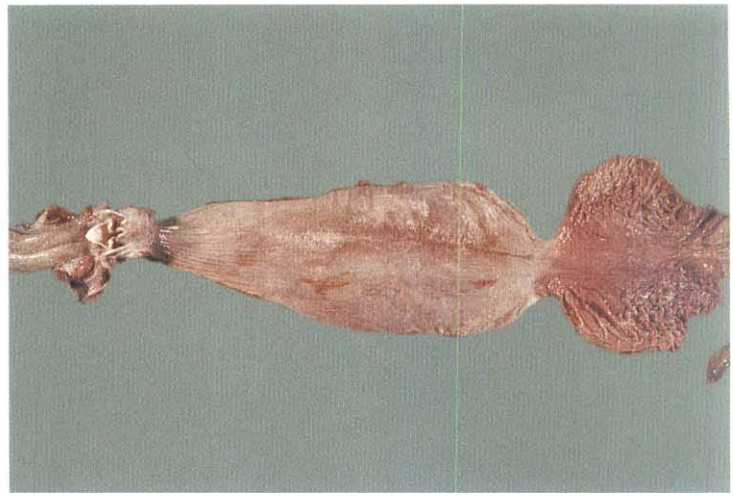
**6-11** Ameloblastoma
A firm nodule of soft tissue growing expansively, destroying a large portion of the normal mandible at the site of the first right incisor tooth. Cow.



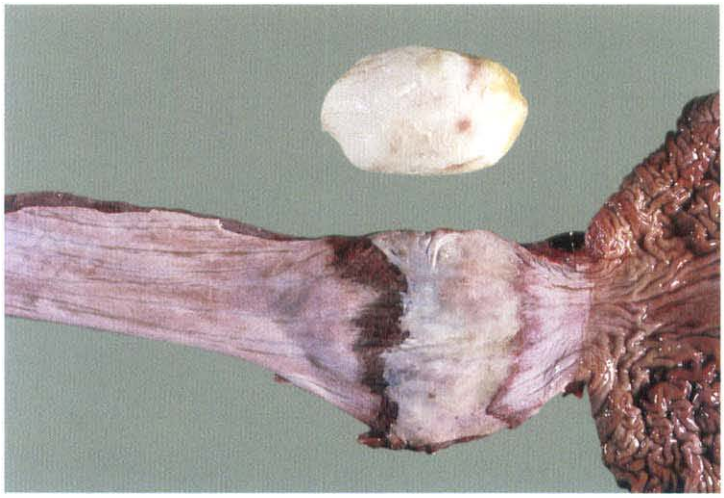
**6-12** Ameloblastoma
Infiltrating and destructive, but non-metastasizing tumor. In a collagenous stroma are irregular islands consisting of a centre with loosely connected, angular stellate cells, surrounded by a layer of cuboidal or columnar cells, which are similar to normal ameloblasts. Cow. HE.



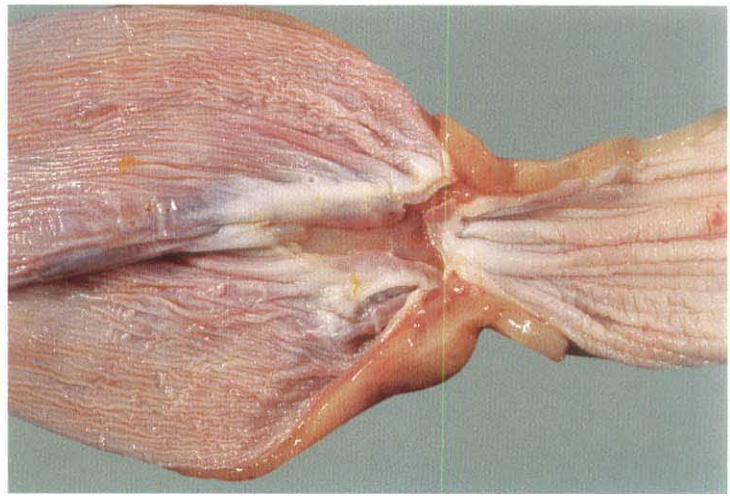
**6-13** Ranula
A cystic distention (arrow) of the sublingual salivary duct, or a salivary mucocele caused by saliva leaking from this duct into the connective tissue in the floor of the mouth. Dog.



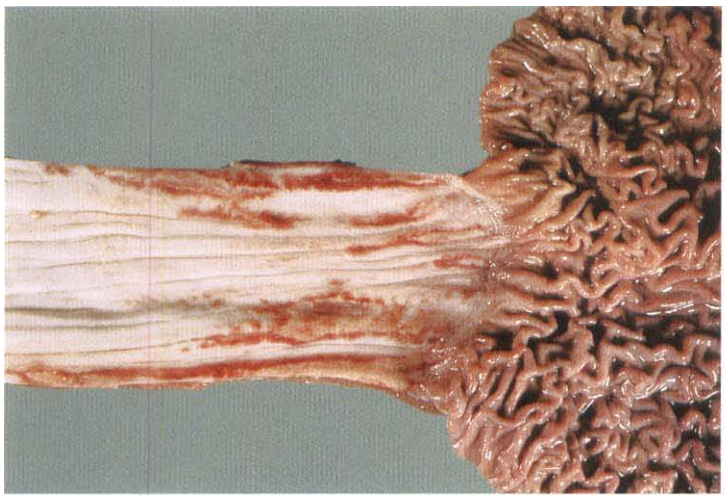
**6-14** Megaesophagus
The dilation, which involves the whole circumference of the esophagus, is most obvious in the thoracic region. Erosive esophagitis caused for example by food stagnation or regurgitation. Possibly congenital. Young dog.



**6-15** Esophageal obstruction
A foreign body (potato) in the distal esophagus causing coagulation necrosis, demarcated by an acute inflammatory reaction. Dog.



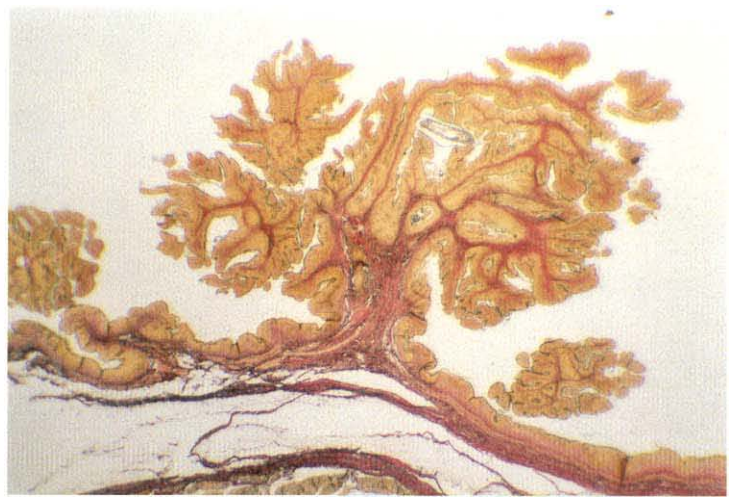
**6-16** Stenosis of the esophagus
Local ulcerative esophagitis and cicatrization causing constriction of the lumen. Leukoplakia at the proximal border of the ulceration. Dilation of the proximal esophagus. Foal.



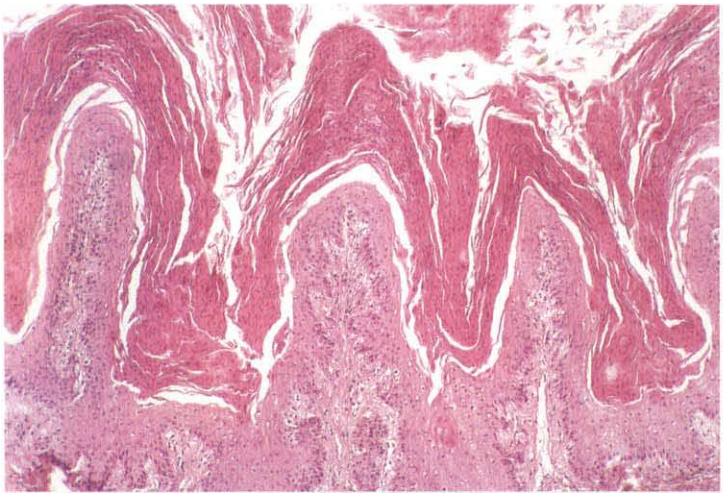
**6-17** Reflux esophagitis
Linear erosive inflammation of the distal esophagus, more diffuse near the cardia, resulting from protracted vomiting and exposure to a combination of gastric juice (hydrochloric acid and pepsinogen) and bile. Dog.

**6-18** Sarcosporidiosis
Excised portions of esophagus and trachea (below). Ovoid, white nodules, projecting from the adventitial surface of the esophagus. The cysts are located in the striated musculature. *Sarcocystis gigantea* (syn. *S. ovifelis*). Sheep.

**6-19** Esophageal papillomatosis
Multiple papillomas covering the whole esophageal mucosa, causing stenosis of the lumen. The virus induced papillomata are pedunculated or sessile with a rough surface, giving a cauliflower appearance. Cow.



**6-20** Esophageal papilloma
The tumorous epithelium is continuous with the normal squamous epithelium. Arborescent connective tissue cords are arising from the underlying mucosal stroma. Cow. Van Gieson.

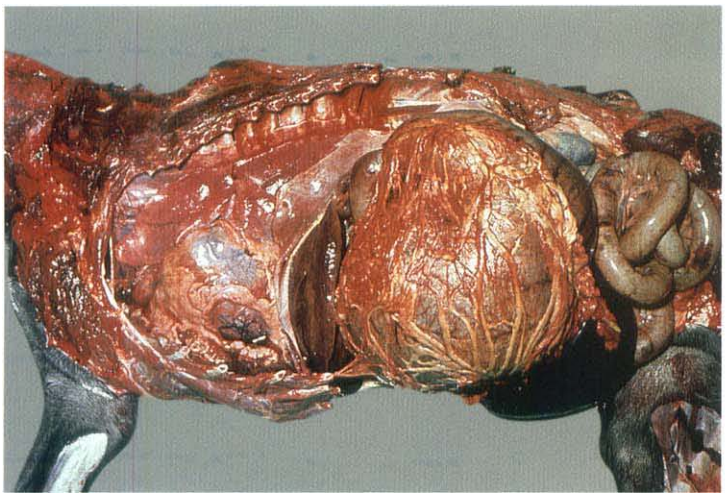


**6-21** Parakeratotic hyperkeratosis
Rumen. Excessive thickness of the stratum corneum, which may be caused by an increased rate of production and/or a decreased exfoliation. In addition, parakeratosis is present. Cow. HE.

**6-22** Chronic necrobacillary rumenitis
Multiple necrotic lesions surrounded by scar tissue. *Fusobacterium necrophorum*. Cow.

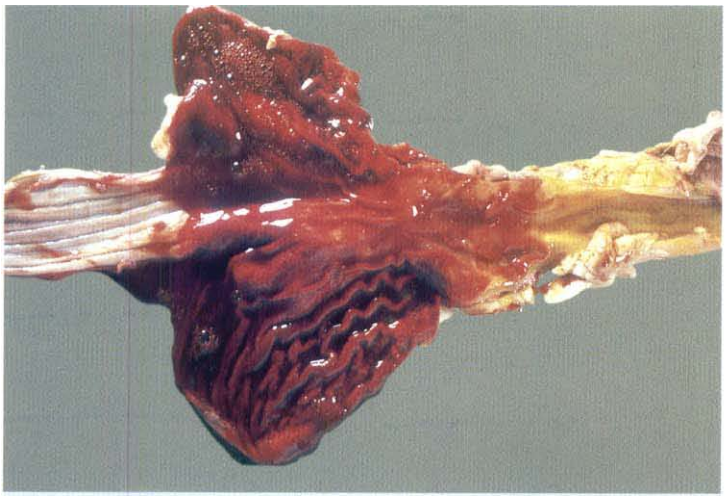
**6-23** Traumatic reticulitis
A mucosal fold has been penetrated by a nail which has caused a granulomatous inflammation without perforation of the reticulum wall. Cow.

**6-24** Fibroma
Forestomach. Multiple fibromata with a smooth surface consisting of a thin layer of squamous epithelium, in the area of the esophageal groove. As a result, disturbance of regurgitation may occur. Cow.



**6-25** Gastric dilation/volvulus syndrome
A clockwise torsion of the stomach with passive congestion of the stomach wall. The spleen has rotated with the stomach, and had assumed a V configuration at its middle. Great Dane. Dog.

**6-26** Gastric edema
Thickened mucosal folds, especially in the fundus and corpus, caused by severe edema of the mucosa and the submucosa. Often in combination with protein-losing enteropathy. Dog.

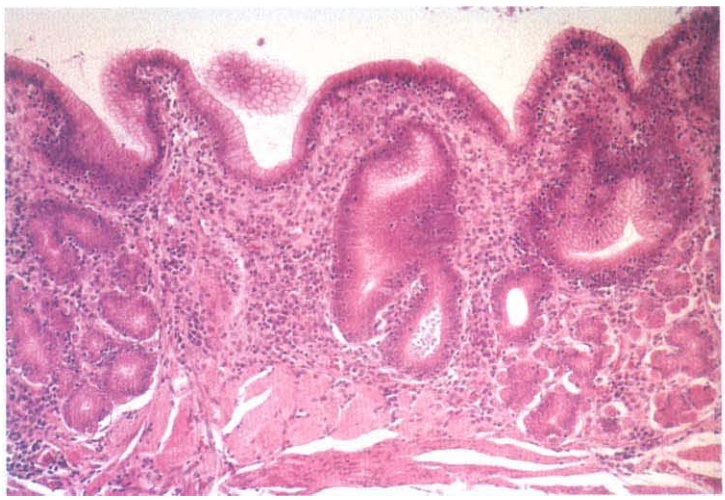


**6-27** Uremic gastropathy
Diffuse redness of the mucosa caused by active hyperemia and hemorrhages; in the lumen, free blood and mucus without ingesta. This pattern also resembles a hemorrhagic gastritis. Dog.

**6-28** Ostertagiosis
Abomasal mucosa. Proliferative abomasitis characterized by diffuse, irregular thickening of the mucosa caused by an infection with *Ostertagia ostertagi*. Cow.

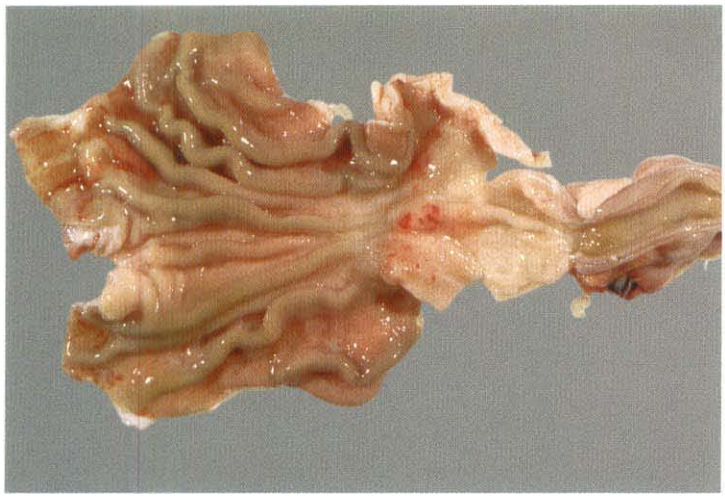
**6-29** Familiar stomatocytosis hypertrophic gastritis syndrome
Irregular thickened mucosal folds, especially in the fundus and corpus, caused by a proliferative inflammation. The macroscopic appearance, reminiscent of the gyri and sulci of the brain, resembles that of Menetrier's disease in man. Specific for the Drentse patrijshond. Dog.

**6-30** Hypertrophic gastritis
Folding of the corpus mucosa caused by glandular hyperplasia and folding of the muscularis mucosae and submucosa. Focal cyst formation. Drentse patrijshond. Dog. HE.

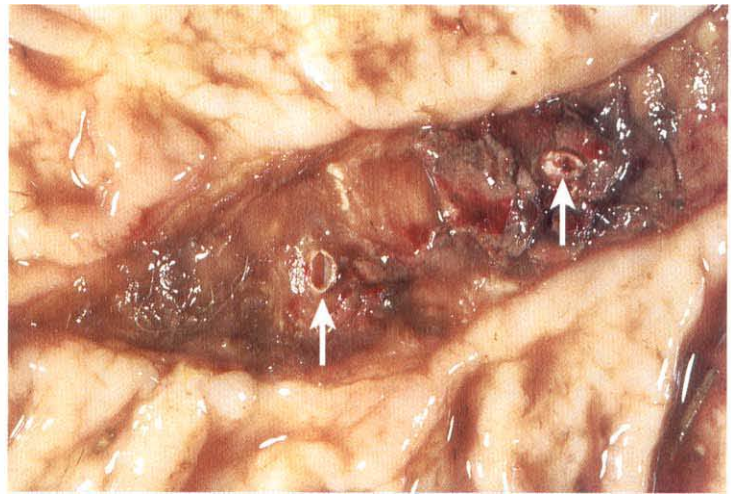


**6-31** Atrophic gastritis
Decrease of the mucosal thickness. Loss of fundic glands with pseudopyloric metaplasia (left) and diffuse round cell infiltration. Dog. HE.

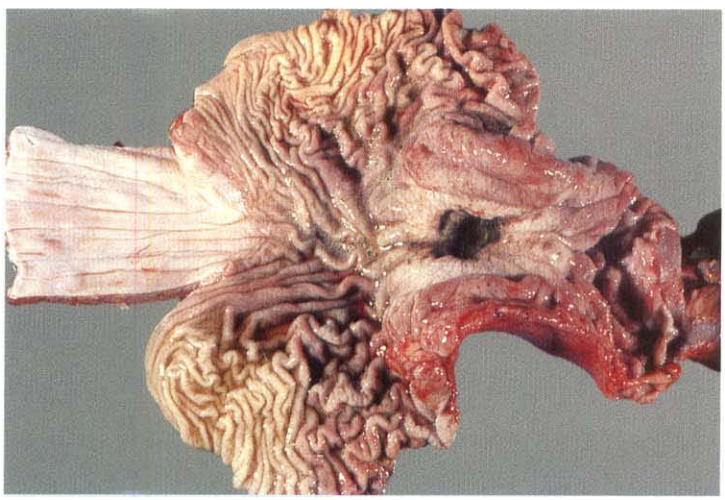
**6-32** Follicular gastritis
White spots in the mucosa caused by an increased number and size of lymphoid follicles. Such a picture can also occur in lymphoma. Dog.



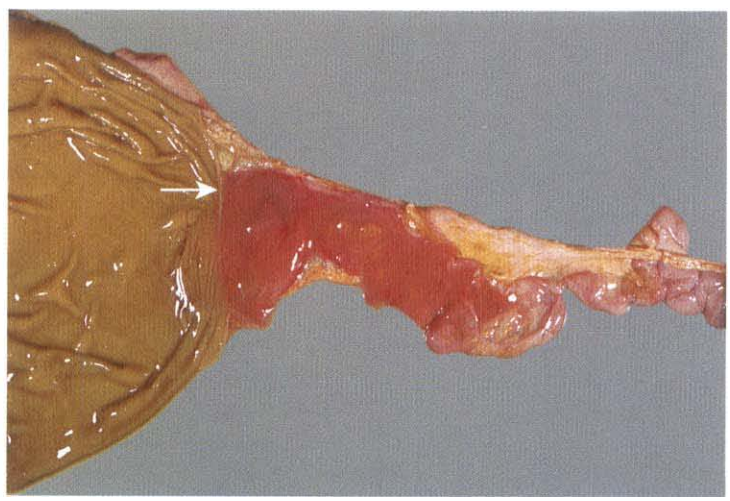
**6-33** Gastric erosion
Multiple erosions in pylorus. Such defects are recognized as significant complications of many diseases and of drug therapy, nonsteroidal anti-inflammatory drugs (NSAIDs) being one of the most common causes. Cat.



**6-34** Gastric ulceration
Large ulcer on the greater curvature of the abomasum, with damage of two blood vessels (arrows), which resulted in fatal hemorrhage. Cow.

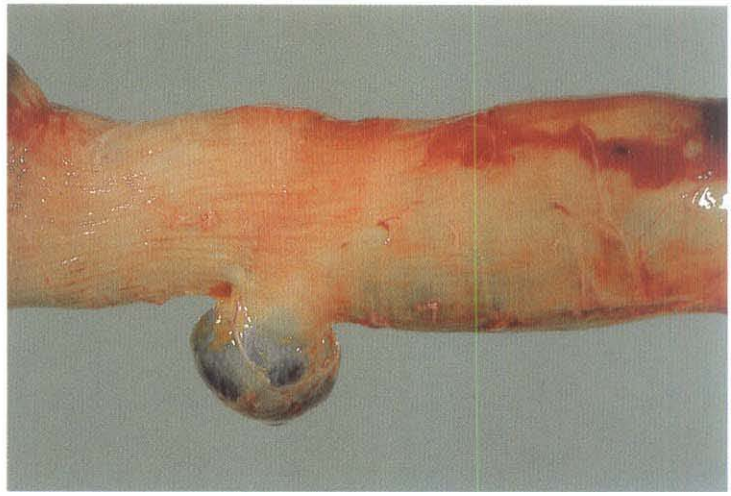


**6-35** Gastric carcinoma
Circular stenosing scirrhous carcinoma with deep ulceration at the transitional zone between the corpus and antrum (predilection area). Dog.

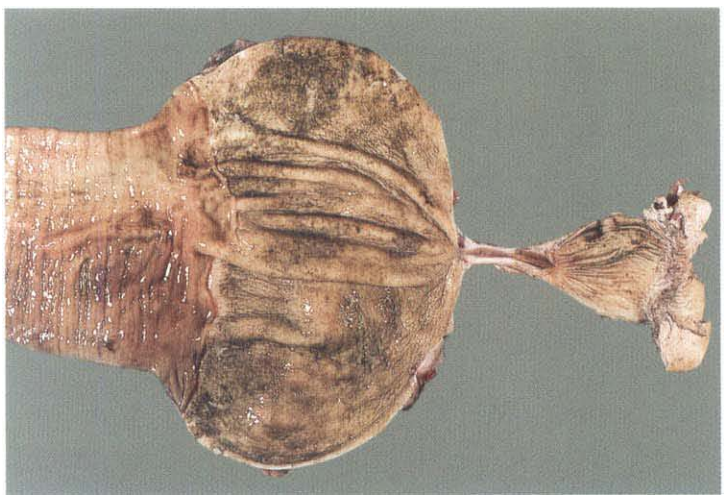


**6-36** Small intestinal membrane atresia
Jejunum (opened). Focal obstruction formed by a membrane (arrow) with dilation of the intestinal lumen proximal to the occlusion site. The membrane consists of connective tissue covered bilaterally by a mucosal layer. Two other types of intestinal atresia are cord and blind-end atresia. Calf.

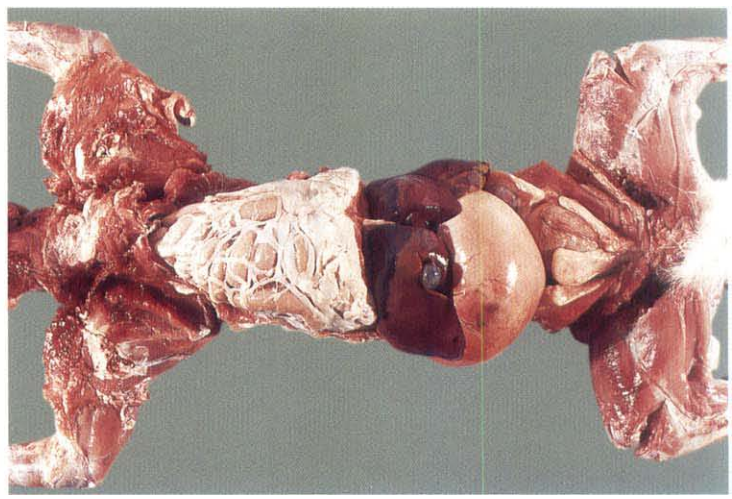
**6-37** Atresia ani
Persistence of the anal membrane, resulting in bulging of the perineal region. Rectovaginal fistula. Swollen belly. Siamese kitten, 12 days.



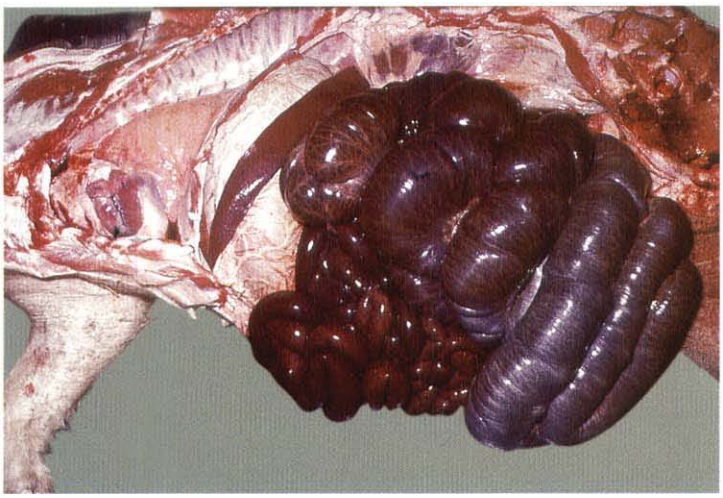
**6-38** Intestinal diverticulum
An outpouching of the colonic lumen; such a diverticulum may be congenital or acquired. Cow.



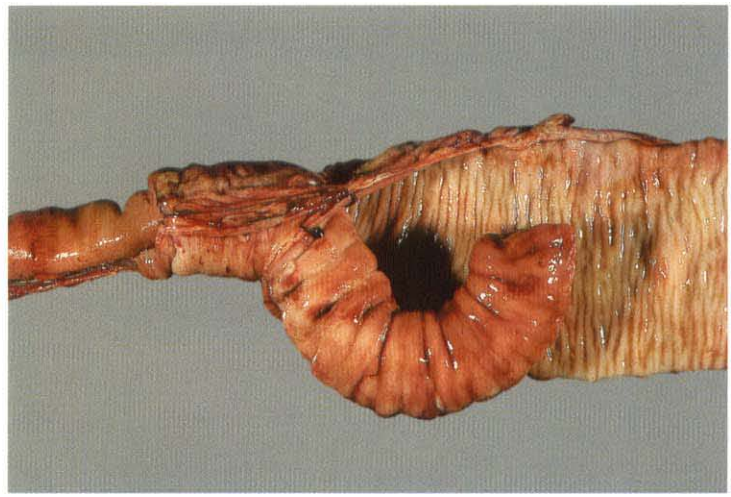
**6-39** Rectal stricture
A long severe stricture, about 10 cm proximal to the anus, with dilation and ulceration of the proximal rectum; there is a sharp border between the dilated rectum and the colon, which is also dilated and has a ribbon pattern caused by circular muscle hypertrophy. Often occurring after rectal prolapse. Pig.



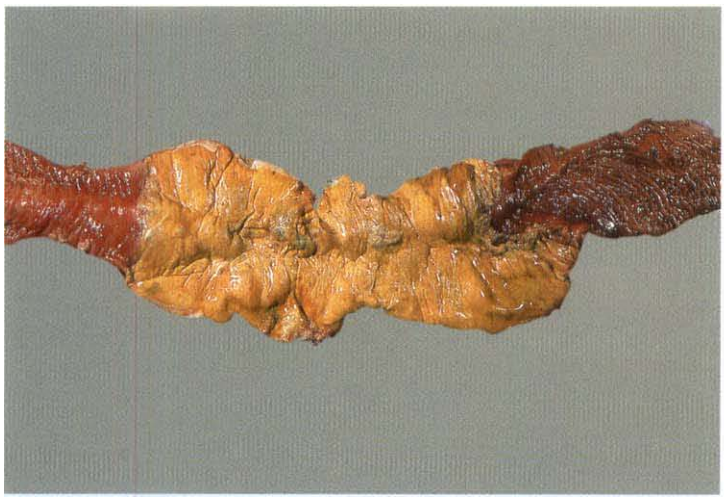
**6-40** Hernia diaphragmatica
Acquired rupture of the diaphragm. Displacement of omentum and small intestine into the pleural cavity. Cat.



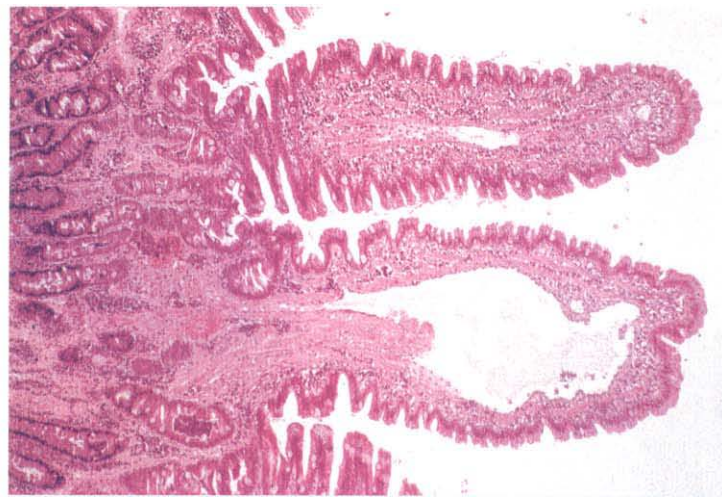
**6–41** Volvulus
360° clockwise rotation of the small and large intestines. Intestinal dilation. Passive congestion of the intestinal wall. Pig.



**6–42** Intussusception
Small intestinal intussusception, producing a three-layered tube. Passive congestion and edematous swelling of the intussuscepted intestinal segment. German shepherd dog.

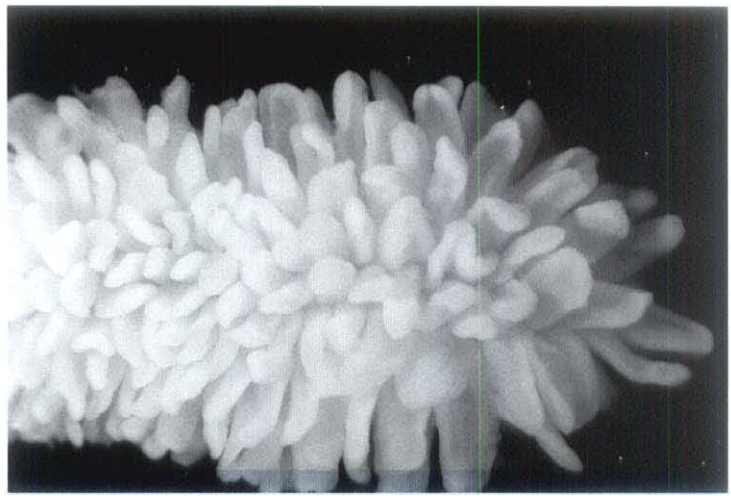


**6–43** Infarction
Clearly defined area of ischemic coagulation necrosis in the jejunum. Foal.

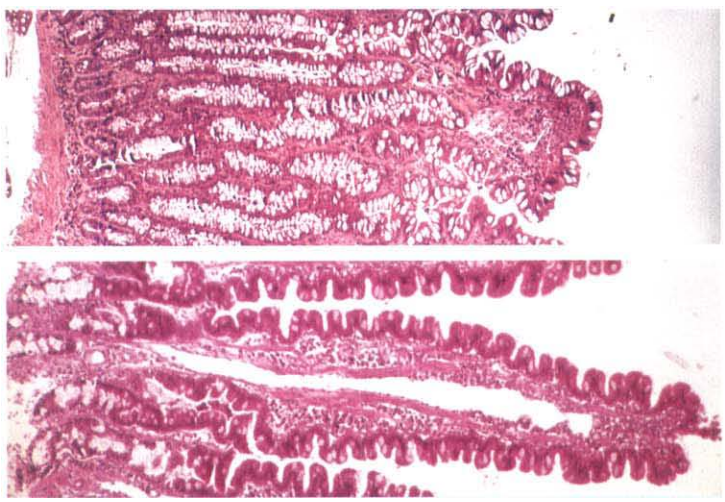


**6–44** Protein-losing enteropathy
Ectasia of a lymphatic lacteal in a jejunal villus. Dog. HE.

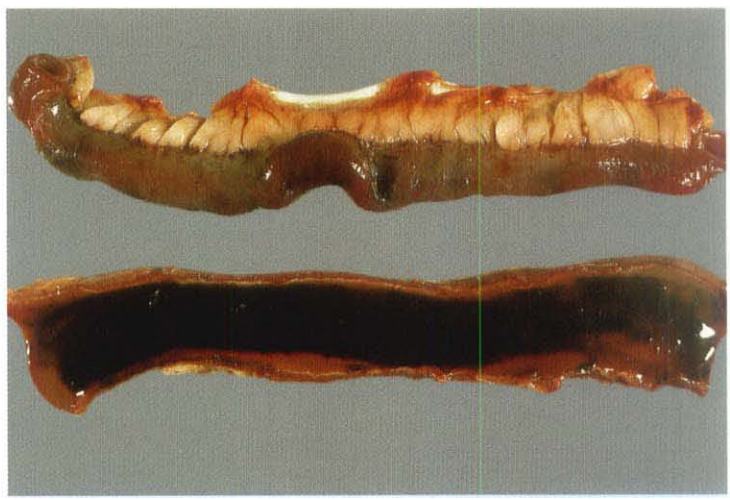
**6-45** Acute catarrhal enteritis
Small intestine. Hyperemia and swelling of the mucosa with an increased amount of mucus overlying a Peyer's patch as can be found in Bovine Virus Diarrhoea-Mucosal Disease (BVD/MD). Cow.



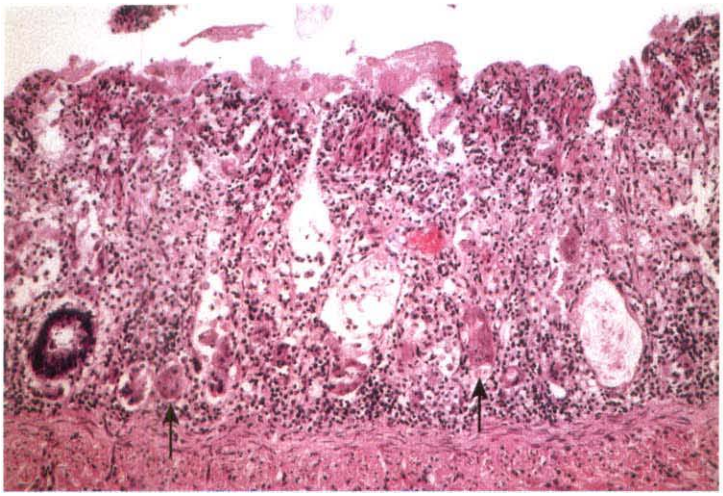
**6-46** Villous atrophy
Duodenum, stereomicroscopic view. Broad leaf- and tongue-shaped villi. Calf.



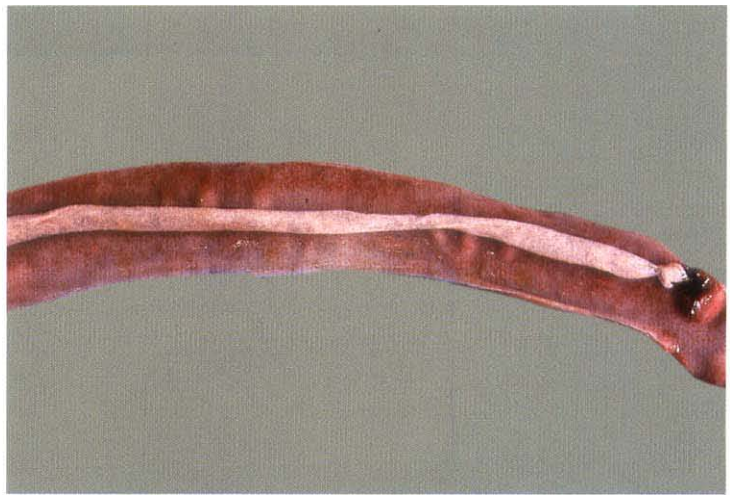
**6-47** Hyperregenerative villous atrophy
Duodenum. Short villi with elongated crypts; in addition, increased number of goblet cells and a slightly increased cellular infiltration of the lamina propria (top). Control (bottom). Dog, 8 years. HE.



**6-48** Hemorrhagic enteritis
Jejunum. Severe redness of the mucosa (below) as a result of active hyperemia and hemorrhage. Free blood in the lumen. Irregular serosal surface (upper), which also is hyperemia. Parvovirus infection. Young dog.



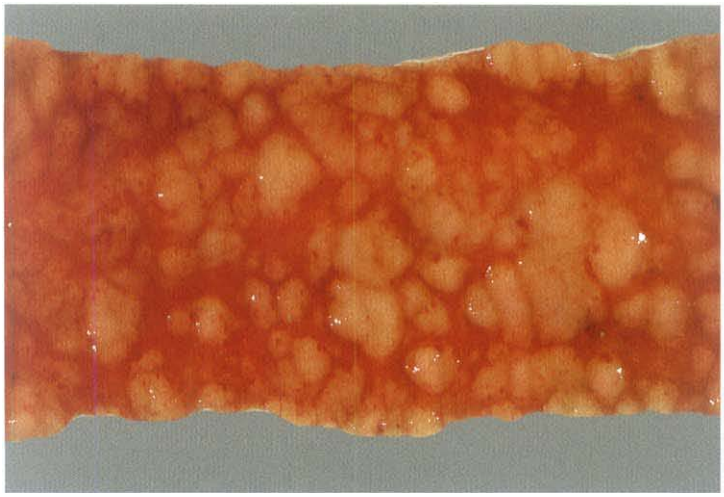
**6–49** Hyporegenerative villous atrophy
Jejunum. Remnants of villi and damaged crypts with alteration of crypt cells. Syncytial giant cells (arrows), superficial necrosis, slight active hyperemia and increased number of mononuclear cells and neutrophils. At the left a less altered crypt is visible. Parvovirus infection. Dog. HE.



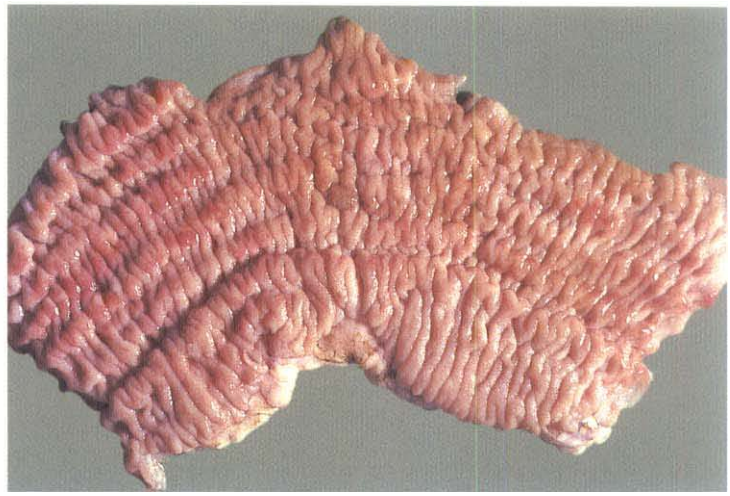
**6–50** Acute fibrinous enteritis
Jejunum. Redness caused by active hyperemia. A yellowish fibrin cast on the mucosal surface. Parvovirus infection (panleukopenia). Cat.

**6–51** Fibrinous-necrotizing enteritis
Ileum. Irregular serosal surface reminiscent of the gyri and sulci of the brain (left). A diffuse thick layer of fibrin and coagulation necrosis is adherent to the mucosa (diphtheritic membrane, right). Salmonellosis. Similar changes can be caused by *Lawsonia intracellularis*. Pig.

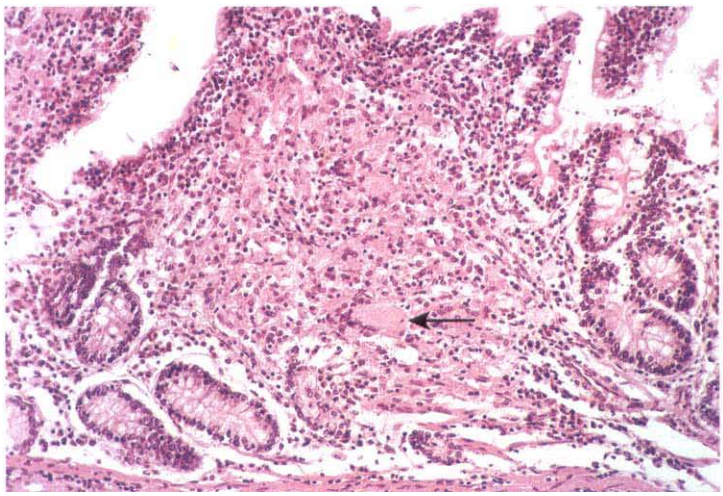
**6–52** Fibrinous-necrotizing enteritis
Colon. Irregular areas of enteritis, sometimes covered by fibrin (black arrow), sometimes with hyperemic defects (white arrow) surrounded by a black rim of pseudomelanosis (so-called 'map design'). Pig.



**6-53** Erosive enteritis
Jejunum, mucosal surface. Extensive erosive enteritis (red) with pale islands of remaining mucosa. Dog.

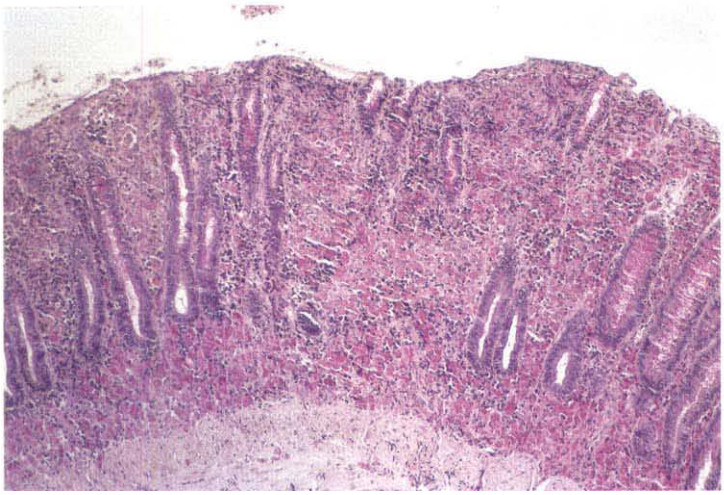


**6-54** Proliferative enteritis
Jejunum. Severe circular folding caused by mucosal thickening. Paratuberculosis (*Mycobacterium avium* subspecies *paratuberculosis*). Cow.



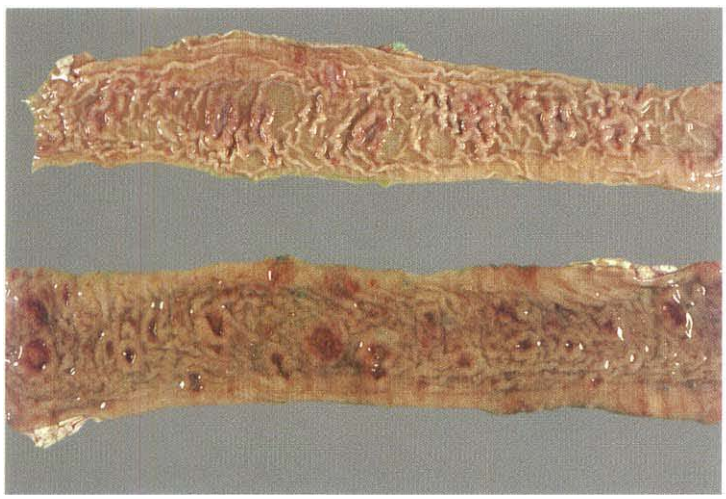
**6-55** Proliferative enteritis
Jejunum. Thickening of the mucosa caused by an accumulation of small lymphocytes, large epitheloid cells and multinucleated Langhans-type giant cells (arrow). Granulomatous inflammation, predominantly in the villi. Paratuberculosis (*Mycobacterium avium* subspecies *paratuberculosis*). Cow. HE.

**6-56** Canine histiocytic ulcerative colitis (CHUC)
Colon. Irregularly thickened wall caused by a proliferative enteritis; extensive ulceration with focal remnants of mucosa (white areas). Boxer dog.



**6-57** Canine histiocytic ulcerative colitis (CHUC)
Thickening of the mucosa by granulomatous inflammation characterized by lymphocytes, plasma cells and PAS-positive histiocytes. The histiocytes are mainly located at the basal layer of the lamina propria. Boxer. Dog. PAS.

**6-58** Atrophic colitis
Colon, forceps biopsy. Proliferative inflammation characterized by round cell infiltration. Reduced mucosal thickness. Decreased number of crypts of Lieberkühn. Dog. HE.



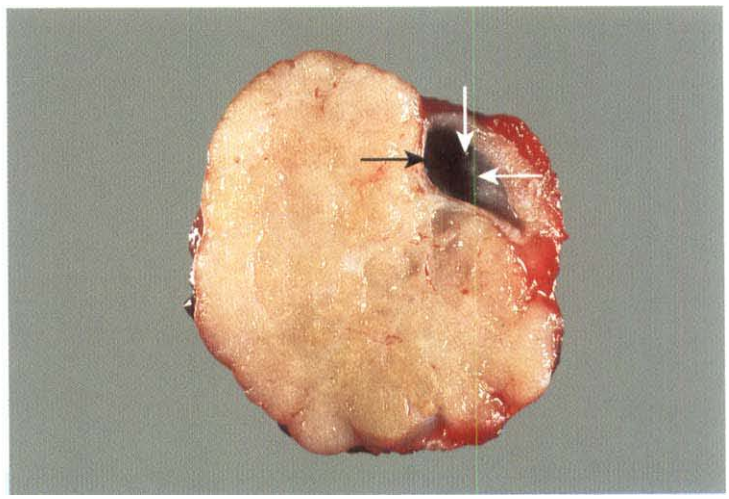
**6-59** Tuberculosis
Jejunum. Multiple ulcers with distinct raised edges. *Mycobacterium bovis*. Cow.

**6-60** Tuberculosis
Jejunum. Granulomatous inflammation characterized by confluent caseous tubercles localized in the submucosa. Ulceration in the center of the lesion. *Mycobacterium bovis*. Cow. HE.

**6-61** Coccidiosis
Intestine. Small white foci in the jejunum projecting into the opened lumen (lower left), also visible through the serosa. *Eimeria arloingi*. Goat.

**6-62** Cyathostominosis (Redworm Infestation)
Colon, mucosal surface. Grayish foci, ca.1 mm, due to reaction to the visible fourth stage larvae, or brown-black spots, ca. 0.1 mm, due to hemorrhage ('pepper and salt design'). Horse.


**6-63** Leiomyoma
Duodenum. Neoplastic proliferation of smooth muscle cells at the site of the circular muscle (X). Central calcification. Expansive growth pattern. Gastrointestinal leiomyomas may induce a paraneoplastic syndrome characterized by hypoglycemia, as a result of synthesis and release of an insulin-like growth factor II-like peptide. Dog. HE.



**6-64** Anal sac carcinoma
A carcinoid tumor originating from apocrine glands of the anal sac (arrow). This tumor can produce and release parathormone-related peptide (PTHrP) resulting in bone resorption (pseudohyperparathyroidism). Dog.

Chapter 7

# The pancreas (exocrine)



## THE PANCREAS (EXOCRINE)

The most common lesions occurring in the pancreas include:

- congenital anomalies (for example hypoplasia and ectopic splenic tissue in the pancreas);
- regressive changes (for example atrophy, calculi and necrosis);
- hyperplasia;
- inflammation; and
- neoplasia.

Lipomatosis with loss of acinar tissue and replacement by fat cells is seen in old dogs. Most congenital anomalies have only limited or no clinical significance.

### *Hyperplasia*

*Nodular hyperplasia* of exocrine pancreatic tissue is a common finding in old animals.

### *Inflammation*

Functionally, very important lesions of the exocrine pancreas are *acute* and *chronic inflammations*.

#### Acute hemorrhagic and hemorrhagic-necrotizing pancreatitis

*Acute hemorrhagic* and *hemorrhagic-necrotizing pancreatitis*, though infrequent, often are fatal lesions; they may be induced by mechanical trauma (sometimes even after surgical manipulation) but pancreatic proteolytic enzymes may also be released otherwise, for instance by an impaired microcirculation during shock.

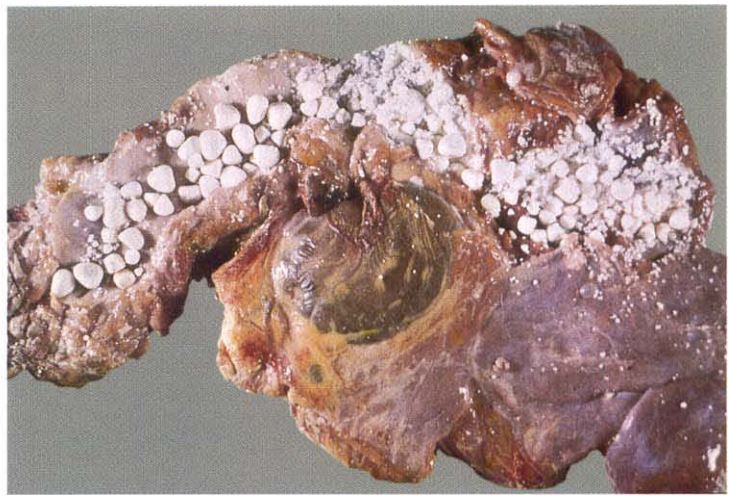
#### Chronic pancreatitis

*Chronic pancreatitis* is rather common and may be hypertrophic or atrophic. Sometimes, it is due to an ascending inflammation of the ducts, caused by a bacterial infection or a parasitic infestation (ascariasis!) in the small intestine.

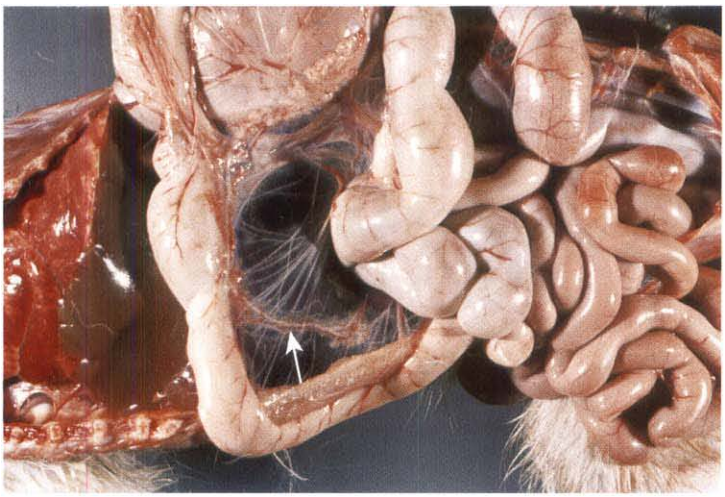
### *Neoplasia*

*Neoplasms* of the exocrine pancreas are rare, although carcinomas do occur.

**7-1** Ectopic splenic tissue
Pancreas with a protruding red nodule (lower left) in the lobus sinister, composed of splenic tissue with normal red and white pulpa. Pig.

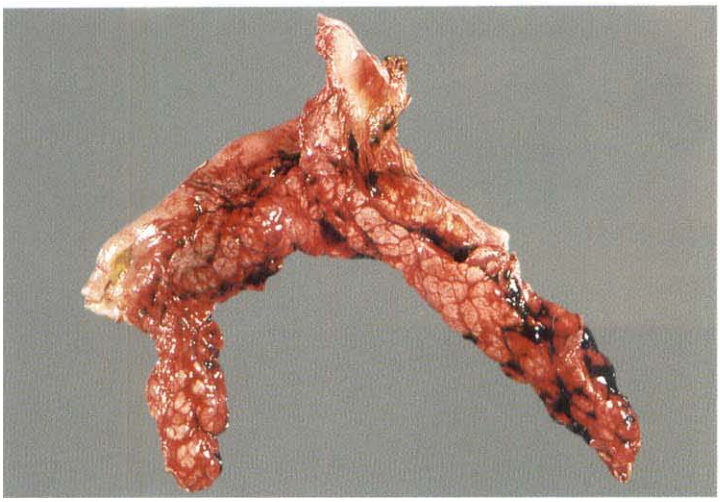


**7-2** Calculi
Hard white stones of variable size in the dilated pancreatic duct. Composed of mineral salts (carbonates and phosphates of calcium). Cow.

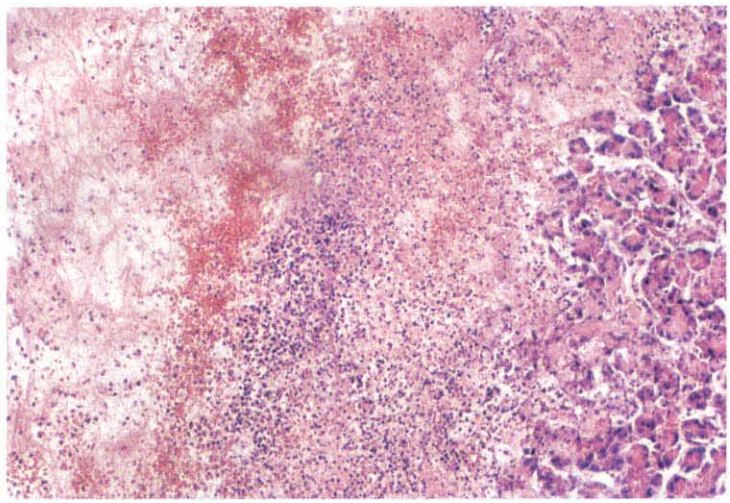


**7-3** Pancreatic atrophy
Flattened remnants of pancreatic tissue (in mesentery of duodenum) with obvious pancreatic ducts (arrow). Overfilling of the small intestine caused by exocrine pancreatic dysfunction. Pancreatic atrophy can be induced by malnutrition or cachexia or may result from postinflammatory fibrosis and/or obstruction of the ducts. It is frequently reported in dogs six months to one year of age. German shepherd dog.

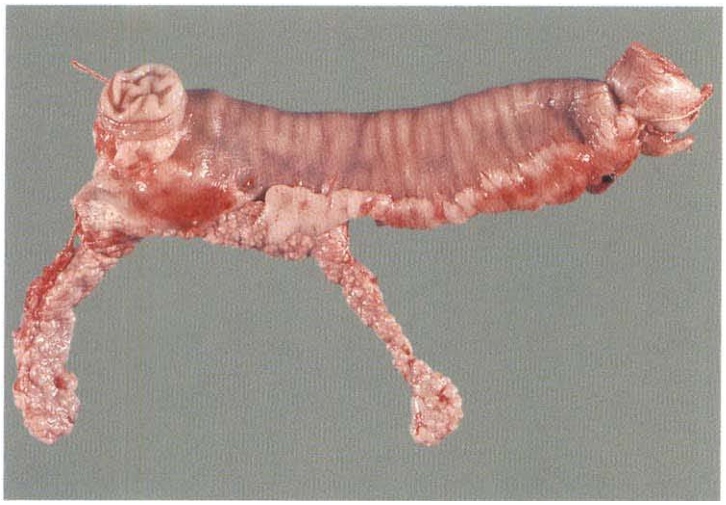
**7-4** Pancreatic necrosis
Cut surface of pancreas. Multiple discrete yellowish-white, dull-surfaced spots of coagulation necrosis. Pig.



**7–5** Hemorrhagic pancreatitis
Local swelling, redness and edema. Dog.



**7–6** Hemorrhagic-necrotizing pancreatitis
Pancreatic tissue with extensive hemorrhage, infiltration of granulocytes and focal necrosis. Dog. HE.



**7–7** Chronic atrophic pancreatitis
The entire pancreas is reduced in size, irregular, pinkish-white and firm. Dog.

**7–8** Chronic atrophic pancreatitis
Corpus pancreatis and duodenum. Chronic inflammation. Loss of pancreatic tissue, as well as hyperplasia of acini. Dog. HE.

Chapter 8

# The peritoneum



## THE PERITONEUM

The peritoneum consists of a flat mesothelial layer and the underlying connective tissue.

Its main lesions are:

- abnormal abdominal content;
- inflammation; and
- neoplasia.

### *Abnormal abdominal content*

In the abdominal cavity abnormal contents are frequently found. Most often these are ascites, blood or inflammatory exudate, but also foreign bodies, gastrointestinal contents, urine and bile are sometimes encountered.

#### Ascites

*Ascites*, the accumulation of noninflammatory transudate in the peritoneal cavity, due to diminished removal or overproduction of fluid, can occur under different conditions. Liver changes are important causes, next to systemic illnesses with lowered albumin levels (lowered osmotic pressure).

#### Hemorrhages

*Hemoperitoneum* is mostly caused by traumatic injury of the spleen or liver but may result from spontaneous rupture of a tumor, most often a hemangiosarcoma.

### *Inflammation*

*Peritonitis* is very common, and may be differentiated into serofibrinous, fibrinopurulent or hemorrhagic inflammation, localized or more generalized. Peritonitis is often caused by bacteria (*Haemophilus suis, E. coli, Mycobacterium tuberculosis*, etc.), sometimes by parasites (*Fasciola hepatica, Echinococcus*, etc.) or viruses (feline infectious peritonitis, etc.). Peritonitis can also have a toxic/chemical cause by leakage of pancreatic enzymes or bile.

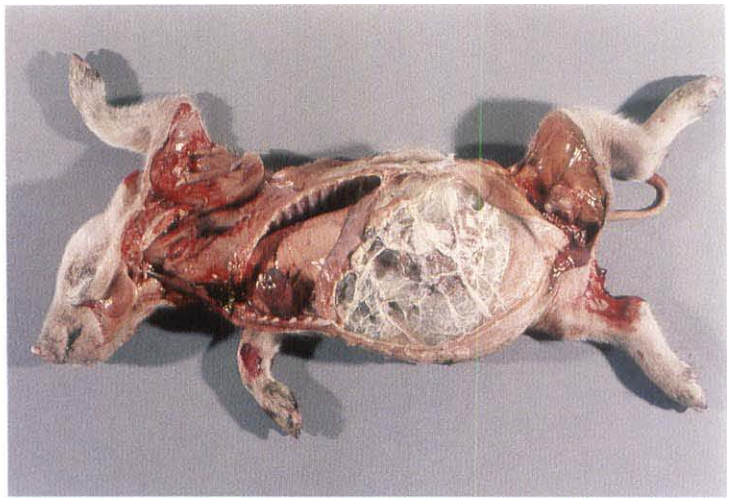
Focal or massive necrosis of omental or retroperitoneal fat can occur, mainly in male cattle. A generalized steatitis, known as *yellow fat disease*, can be caused by hypovitaminosis E and too much unsaturated fatty acids in the diet.

### *Neoplasia*

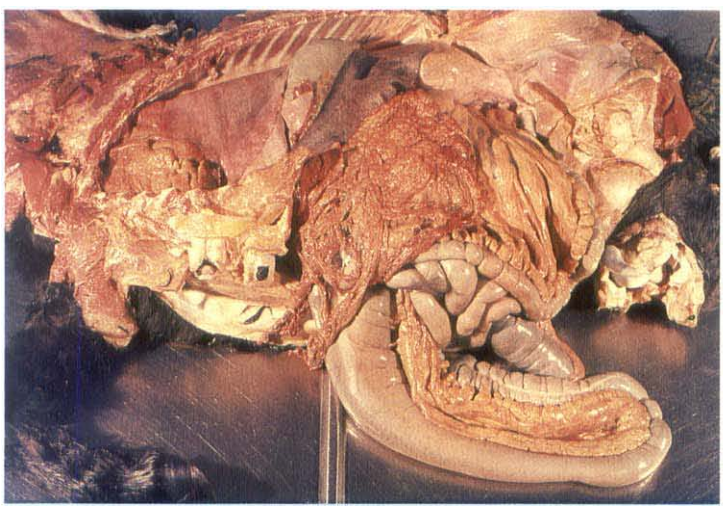
*Primary neoplasms* of the peritoneum are mesothelioma and, especially in horses, lipoma in the mesenteries.

*Secondary neoplasms*, like melanoma or squamous cell carcinoma of the esophageal part of the stomach in horses, are well-known, just as implantations from ovarian tumors.

**8-1** Hemorrhagic colitis
Colon. Redness of the serosa of the spiral labyrinth caused by petechial, ecchymotic and diffuse hemorrhages; a few fibrinous threads are visible on the serosa. Swine fever. Pig.



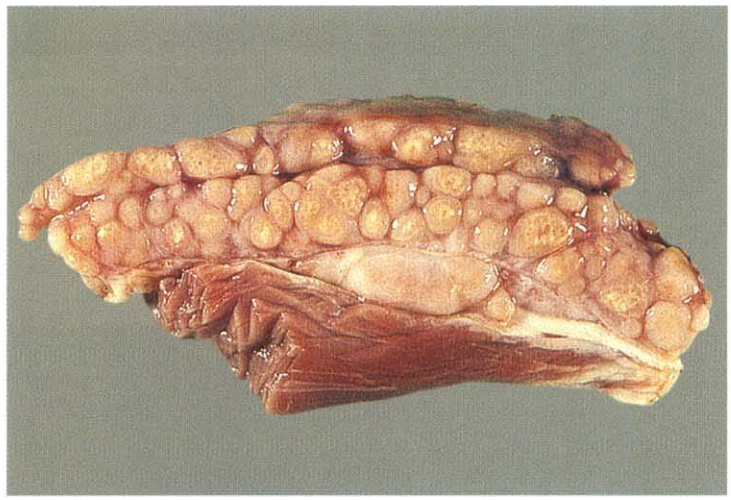
**8-2** Acute serofibrinous peritonitis
Distended abdomen. Inflammatory hyperemia. Yellow-white fibrinous exudate as a solid rubbery plaque on the peritoneum, with a yellow serous exudate. The brown staining of the left hind limb is caused by intramuscular iron injection. Bacterial infection. Piglet.



**8-3** Yellow fat disease
Diffuse steatitis of thoracic and abdominal adipose tissues. Yellow color because of accumulation of ceroid-lipofuscin. Vitamin E deficiency. Horse.

**8-4** Steatitis
Multiple white foci in the abdominal adipose tissue representing focal necrosis. In most cases caused by pancreatic damage. Dog.

**8-5** Feline infectious peritonitis (FIP)
Small intestine and mesentery. Focal depositions of gray fibrinous exudate on the peritoneal surface. In the underlying subserosal tissue, necrosis and a pyogranulomatous inflammation is present. Corona virus. Cat.



**8-6** Tuberculosis
Abdominal wall, cross-section. Conglomerate of grayish translucent nodules surrounded by connective tissue, adjacent to the peritoneal surface. Central caseation necrosis (yellow) with dystrophic calcification (white). *Mycobacterium bovis*. Cow.

**8-7** Cysticercosis
Omentum. Many mature, transparent cysticerci cysts. In some of them a scolex (white spot) is visible. *Cysticercus tenuicollis*. Sheep.

**8-8** Mesothelioma
Parietal peritoneum. Multiple, variable-sized, smooth-surfaced nodules. No caseous necrosis. Remarkable resemblance to the pearly granulomas of bovine peritoneal tuberculosis. Cow.

Chapter 9

# The endocrine glands



## THE ENDOCRINE GLANDS

The endocrine glands include the pituitary, thyroid, parathyroid, adrenal glands and the Diffuse NeuroEndocrine System (DNES).

The hypothalamic–pituitary–endocrine gland axes offer important clues to understand many lesions of the thyroid, adrenal cortex and gonads. Lesions of the endocrine glands include:

- atrophy and degeneration;
- hypertrophy and hyperplasia;
- inflammation; and
- neoplasia.

### *Atrophy and degeneration*

Atrophy of thyroid or adrenals is, in most cases, due to lowered levels of the pituitary trophic hormones TSH or ACTH. This in turn may result from loss of functional pituitary tissue or suppression of pituitary function by iatrogenic administration of thyroid hormone or corticosteroids.

In the parathyroids atrophy results from raised blood levels of calcium.

Pancreatic insular insufficiency with diabetes mellitus can be due to hypoplasia as well as aplasia of the islets of Langerhans, necrosis of the islets (as part of an acute pancreatitis), insular amyloidosis, and destruction by tumor growth. Vacuolar degeneration of insular β-cells and even of epithelial cells of small exocrine pancreatic ducts is often seen in diabetic animals and is thought to be a consequence, not a cause, of diabetes mellitus.

*Degenerative lesions* are not frequent findings in endocrine glands.

### *Hypertrophy and hyperplasia*

*Diffuse hypertrophy* and *hyperplasia* of thyroid or adrenals are associated with raised levels of TSH or ACTH and physiologically, they are signs of adaptation. Such a gland may be hypofunctional in spite of its enlargement, but a normal or raised function is also possible.

Uptake of goitrogens or iodine deficiency may cause *microfollicular hyperplasia* in thyroids. Inborn errors affecting the synthesis of hormones are rare but well-known causes for diffuse hyperplasia of thyroids and adrenal cortex. Absence of a negative feedback to the pituitary (as in congenital hypothyroidism and adrenogenital syndrome or after castration) may induce a diffuse hypertrophy and hyperplasia of the involved type of pituitary cells.

Hyperplasia of parathyroids often indicates a raised level of PTH. It results from hypocalcemia, but it may be present even when hypocalcemia is not (or no longer?) present. High levels of dietary calcium may induce hypertrophy and eventually hyperplasia of calcitonin-secreting parafollicular cells (C-cells).

### *Inflammation*

Inflammation is not a frequent finding in endocrine glands. *Inflammatory destruction* of an endocrine gland (pituitary, thyroid, adrenals) with loss of function is mostly due to infiltration by lymphocytes and macrophages caused by an (auto)immune disorder. Grossly, this may result in severe atrophy.

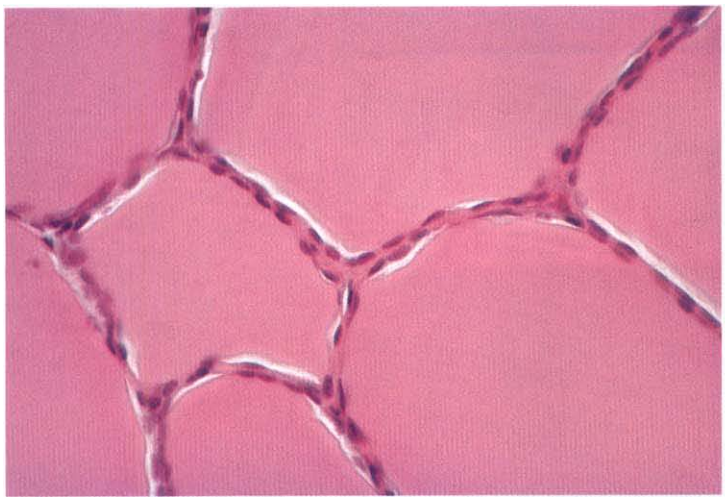
Local or systemic infections, such as tuberculosis, may rarely cause destruction and hypofunction of endocrine glands.

## Neoplasia

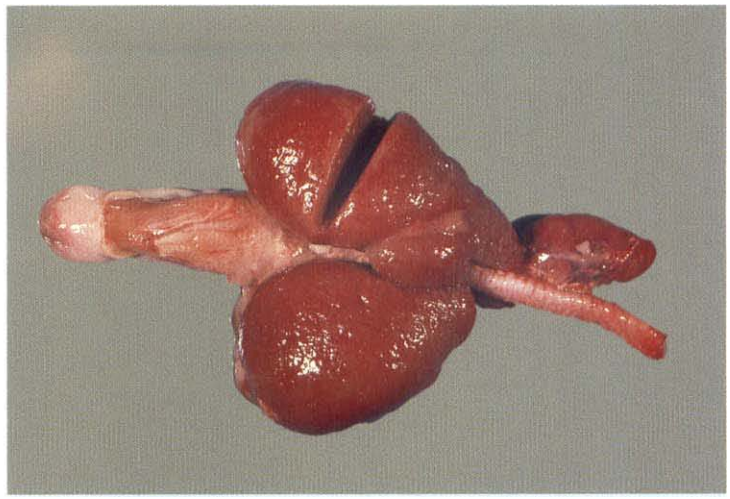
*Neoplasms* of endocrine glands can be an uncontrolled source of hormone, resulting in secondary diseases, such as:

- ACTH producing pituitary tumors with Cushing's disease;
- corticosteroid producing adrenocortical tumors with Cushing's syndrome;
- $T_4$ and $T_3$ producing thyroid tumors with hyperthyroidism; and
- DNES derived tumors, such as calcitonin secreting medullary thyroid carcinoma with hypocalcemia; pancreatic insulinoma with hypoglycemia; gastrinoma with gastric hypersecretion, etc.

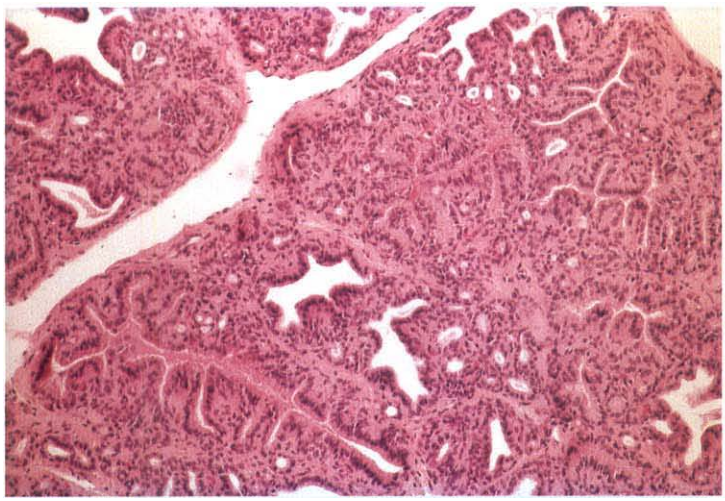
Hyperthyroidism in animals is almost always due to secreting neoplastic (or at least nodular hyperplastic) lesions in the thyroid. Sometimes, the cells in endocrine neoplasms have lost their ability to synthesize and secrete hormones; if such a neoplasm destroys the non-neoplastic part of the endocrine gland by infiltration or pressure the final outcome may be a hypofunction of that gland.



**9-1** Atrophy of thyroid epithelium
Thyroid. Distended follicles, flat epithelial cells. Absence of resorption vacuoles of the colloid at the border with the epithelium: absence of TSH stimulation. Hypophysectomy because of pituitary tumor with Cushing's disease. Dog. HE.

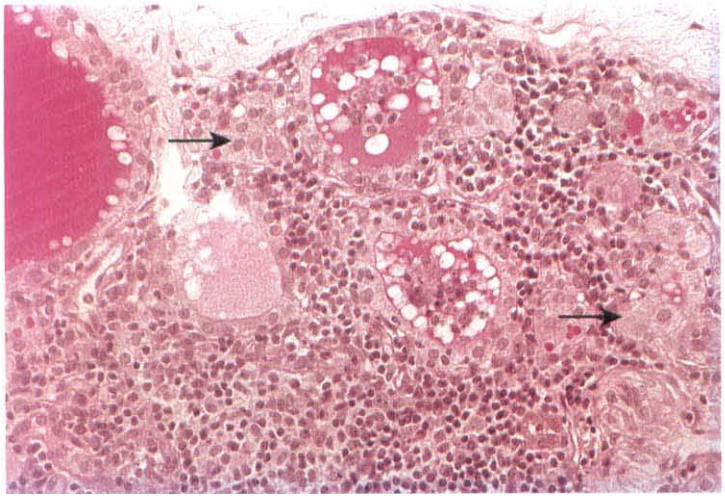


**9-2** Parenchymatous goitre (microfollicular hyperplasia)
Thyroid. Symmetrical enlargement due to diffuse microfollicular hyperplasia, based on hereditary congenital dyshormonogenesis. Small goat (cretin) with sporadic non-toxic goitre due to inability to synthesize normal thyroglobulin and resulting in hypothyroidism. Goat.



**9-3** Parenchymatous goitre (microfollicular hyperplasia)
Thyroid. Hyperplastic stage of goitre. Columnar follicular cells, and small, even slit-like follicles with scanty colloid and papillary proliferation. Sporadic non-toxic goitre due to dyshormonogenesis (defective thyroglobulin synthesis) resulting in hypothyroidism. Goat. HE.

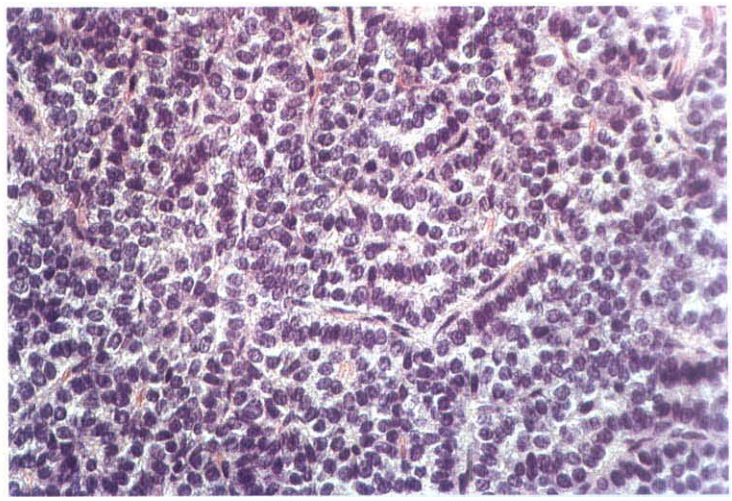
**9-4** Colloid goitre (macrofollicular hyperplasia)
Thyroid. Symmetrical enlargement with severely distended follicles (cysts). In contrast to microfollicular hyperplasia, most epithelial cells are flattened, the septa become atrophic and may disappear. Locally, papillary proliferations occur and hypertrophic cells may still remain. Involutional stage of microfollicular hyperplasia. Sporadic non-toxic goitre due to unidentified type of dyshormonogenesis. Sheep.



**9-5** Lymphocytic thyroiditis
Thyroid. Diffuse infiltration of lymphocytes, plasma cells and macrophages between the follicles with invasion and destruction of the epithelium. Hyperactive normal follicle (upper left) with numerous resorption vacuoles. Relative increase of intact pre-existing calcitonin-producing cells (arrows). Primary, possibly autoimmune, hypothyroidism. Dog. PAS stain.

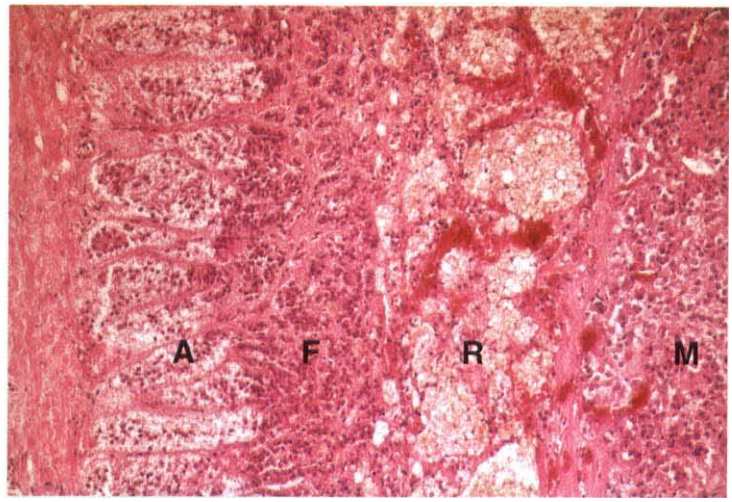
**9-6** Multinodular 'adenomatous' hyperplasia
Thyroid, surface (top) and cut surface (bottom). Enlargement due to multiple hyperplastic nodules. Autonomous hyperthyroidism. Cat. Formalin fixation.

**9-7** Diffuse parathyroid hyperplasia
Parathyroid glands attached to cranial pole of normal-sized thyroids. Bilateral diffuse enlargement of parathyroids (long axis at least 2 × normal length). Secondary renal hyperparathyroidism. Dog.

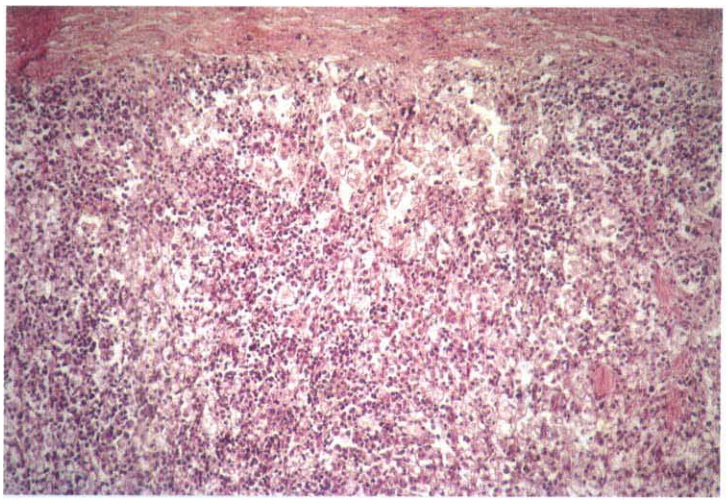


**9-8** Diffuse parathyroid hyperplasia
Parathyroid gland. Hyperplastic and slightly hypertrophic epithelial cells forming sheets or cords, often arranged along blood vessels in a palisading fashion, with the apical cytoplasm directed towards the vessel (pseudoglandular appearance). Secondary renal hyperparathyroidism. Dog. HE.

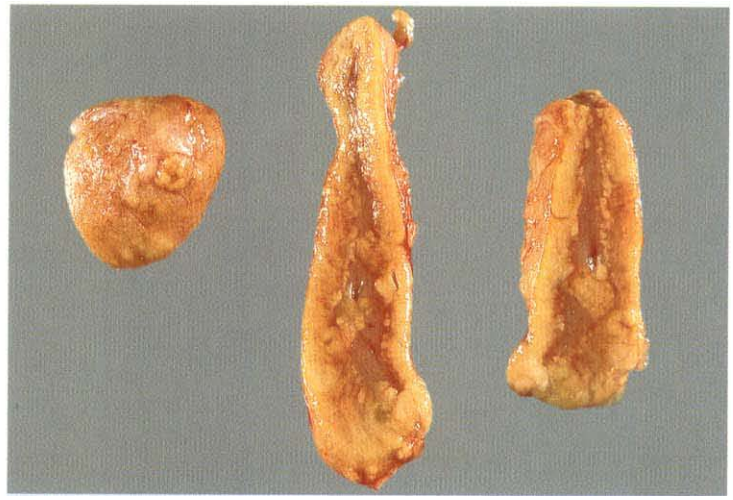
**9–9** Functional adrenocortical carcinoma
Adrenal glands, cut surface. Large yellow tumor of adrenal cortex (left). Cortical atrophy in non-tumorous part (arrow) and in contralateral non-tumorous adrenal gland (right), indicating depressed ACTH stimulation due to hormonally functional tumor. Cushing's syndrome. Dog.



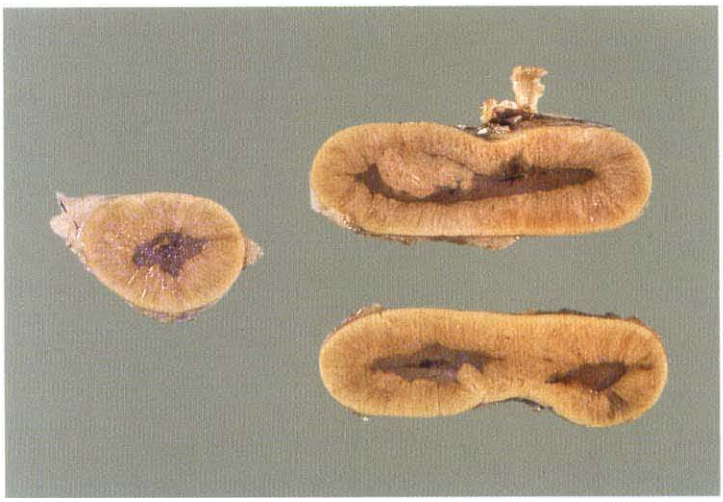

**9–10** Adrenocortical atrophy
Adrenal cortex. Narrowed cortex composed of intact zona arcuata (A) and distinctly atrophic zona fasciculata (F). The zona reticularis (R) is mainly made up of fatty remnants of disintegrated cortical cells. Unaffected medulla (M). Iatrogenic chronic secondary hypoadrenalism after longstanding glucocorticoid administration and suppression of ACTH-output. Similar morphology can be seen after therapeutic o.p.-DDD administration or in presence of functional tumor in opposite adrenal (see Fig. 9-9). A higher dose of o.p.-DDD also involves the zona arcuata, and will result in iatrogenic Addison's disease. Dog. HE.



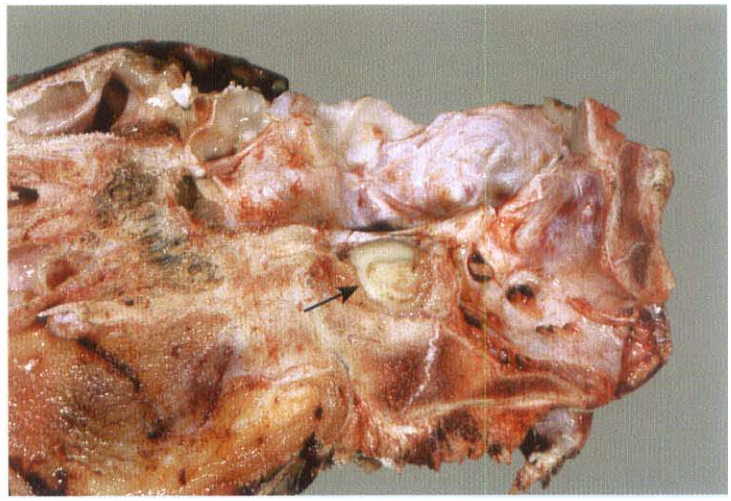
**9–11** Adrenalitis
Adrenal cortex. Round cell infiltrate (mainly lymphocytic) in adrenal cortex (zona arcuata and fasciculata) with destruction of cortical tissue. Possibly due to autoimmunity. Leads to idiopathic atrophy and Addison's disease (chronic primary hypoadrenalism). Dog. HE.



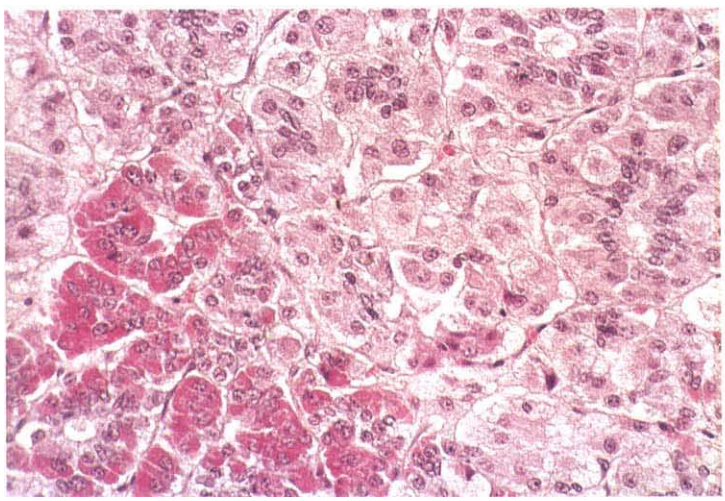
**9–12** Adrenal nodular hyperplasia
Adrenal glands, surface (left), cut surface (right and middle). Yellow spherical nodules in and upon the capsule, in cortex and medulla, the latter two showing normal thickness. Histologically, they consist of tissue as in zona arcuata and/or fasciculata. Common, incidental finding in older animals. Dog, 7 years.



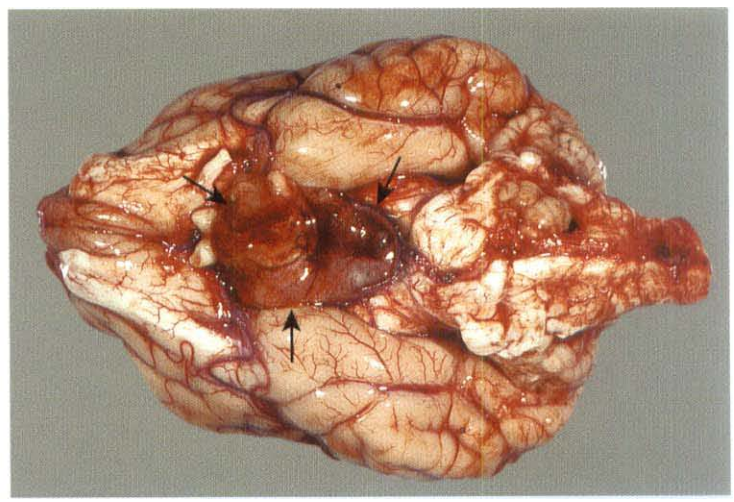
**9-13** Adrenocortical hyperplasia
Adrenal glands, cut surface (formalin fixed). Bilateral diffuse enlargement of cortex due to hyperplasia of zona fasciculata and reticularis. Hyperplastic nodule in medulla (upper right). Caused by increased ACTH-activity, possibly due to tumor of ACTH-producing cells, or congenital cortisol deficiency. Hypercortisolism (Cushing's syndrome). Dog, 8 years.



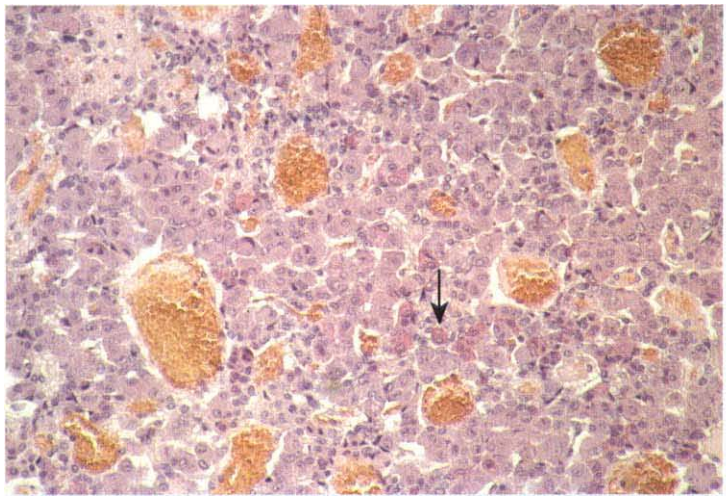
**9-14** Suppurative hypophysitis
Head, median section. Abscess (arrow) below the cranial cavity in the sella turcica and covered by the diaphragma sellae. Remnants of the pituitary in centre of abscess. Cow.



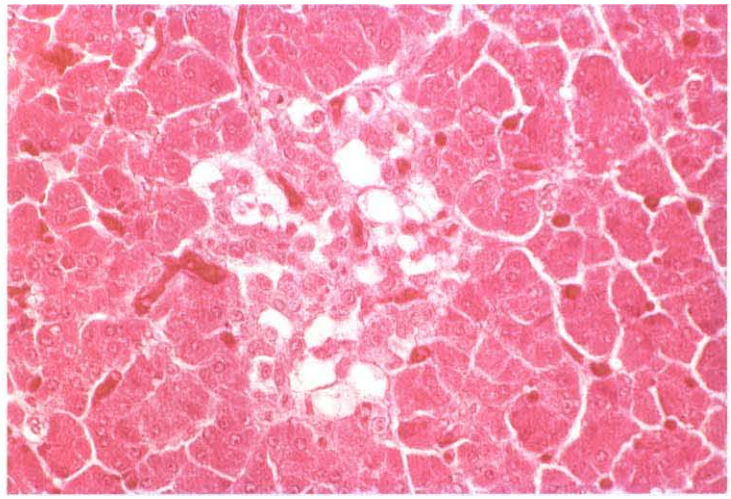
**9-15** Diffuse basophilic cellular hypertrophy and hyperplasia
Pituitary gland, anterior lobe. Diffuse hypertrophy and hyperplasia of basophilic (TSH-secreting) cells. Decreased basophilia is probably due to rapid secretion of granular content. The same morphology is seen after castration, or after stimulation of ACTH-secreting cells. Lower left: normal acidophilic cells. Congenital hypothyroidism due to unidentified type of dyshormonogenesis (see Fig. 9-4). Sheep. HE.



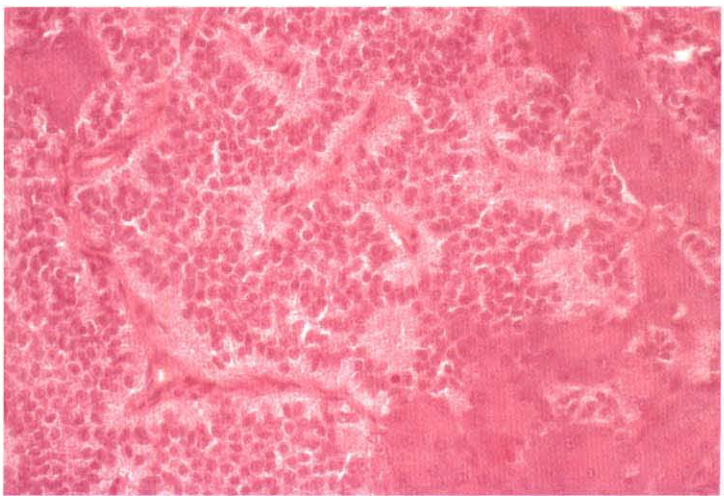
**9-16** Pituitary tumor
Brain. Large, red, tumorous mass (arrows), just behind the optic chiasm. Histologically, proliferation of basophilic cells. Cushing's syndrome; clinical signs related to increased intracranial pressure. Dog.



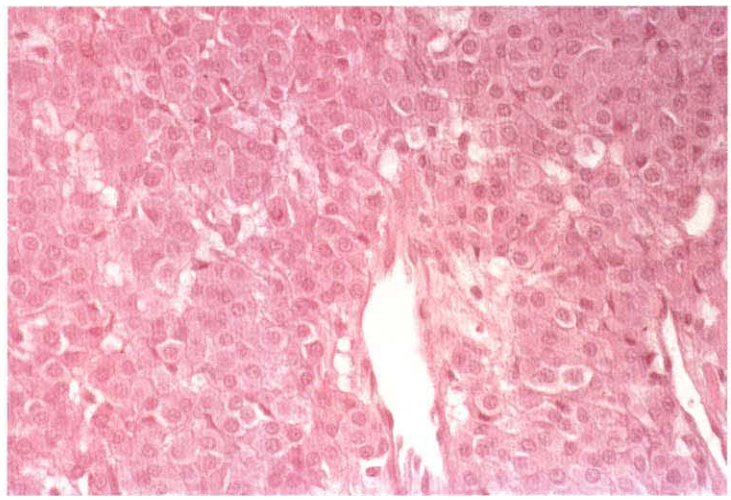
**9-17** Basophilic pituitary tumor
Pituitary gland. Tumor composed of basophilic cells. Many sinusoidal blood vessels. A few pre-existing acidophilic cells (arrow). Cushing's syndrome. Dog. HE.



**9-18** Vacuolar change in islet of Langerhans
Islet of Langerhans surrounded by exocrine pancreas. Large vacuoles containing glycogen and water, often found in β-cells (insulin-secreting cells) of patients with diabetes mellitus. Significance in pathogenesis of diabetes mellitus unclear. Diabetes mellitus. Dog. HE.



**9-19** Pancreatic tumor of DNES cells (gastrinoma)
Pancreas. Tumor cells (gastrin-secreting cells) in sheets, and arranged along small blood vessels; cytoplasm directed to the vessel for secretion of hormone. Non-tumorous area of pancreatic acini (right). Same morphology in insulinoma. Gastrin hypersecretion, resulting in gastric acid hypersecretion (Zollinger–Ellison syndrome). Dog. HE.



**9-20** Tumor of DNES cells (medullary thyroid carcinoma, parafollicular cell or C-cell carcinoma)
Thyroid. Solid mass of calcitonin-secreting, large cells with large pale nuclei and pale granular acidophilic cytoplasm. Mostly found in dogs and aged bulls. Hypocalcemia. Dog. HE.

Chapter 10

# The genital system



## THE GENITAL SYSTEM

The genital system comprises female genital organs, including the placenta; and the male genital organs.
The most common lesions in the genital system include:

- congenital abnormalities;
- ovarian cysts;
- displacement;
- hypertrophy, hyperplasia and metaplasia;
- inflammation; and
- neoplasia.

### *Congenital abnormalities*

*Congenital abnormalities* can be found at all levels, from the gonads to the vagina or prepuce, including the accessory glands. Absence or hypoplasia and defective differentiation in male or female direction can often be explained by disturbances in embryological or fetal development and hormonal or chromosomal aberrations.

### *Ovarian cysts*

*Ovarian cysts* most frequently originate from Graafian follicles.

### *Displacement*

*Displacement* of the genital organs can affect the uterus (e.g. torsion), placenta (e.g. chorionic invagination) or testicle (e.g. abdominal cryptorchidism or torsion of the spermatic cord).

### *Hypertrophy, hyperplasia and metaplasia*

*Hypertrophy* and *hyperplasia* as spontaneous disorders frequently occur in the canine endometrium (*cystic endometrial hyperplasia, CEH)* and prostate gland. These lesions mostly result from disturbances in the levels of sex steroids. In farm animals these abnormal proliferations, often with *metaplasia* to (cornifying) squamous epithelium in the glands of Bartholin and the prostate gland, are mostly caused by (illegal) use of growth promoting steroids.

Squamous metaplasia also occurs in the placenta (amniotic plaque).

## Inflammation

Inflammation is mostly caused by ascending infections after parturition or mating or by hematogenous infections.

In females, mostly the uterus is involved (*endometritis, metritis*). During pregnancy also the cotyledon/caruncle complexes and the fetal membranes may be inflamed. Endometritis of a pregnant uterus often results in fetal death and abortion. Severity may range from a serous inflammation to a fibrinous-necrotizing one, sometimes with accumulation of much suppurative exudate (*pyometra*) in the uterine cavity. In dogs a pyometra is often associated with cystic endometrial hyperplasia. *Chronic endometritis* often is the cause of reduced fertility.

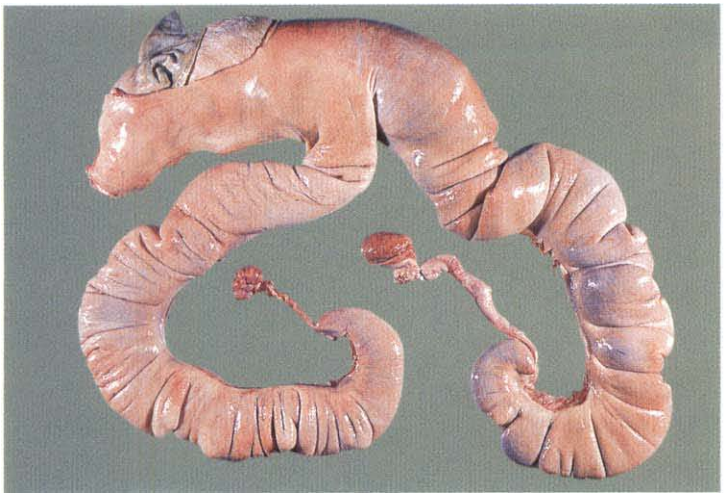
In the mare endometrial cups may mimic ulcers.

In males, nonspecific infections by a variety of organisms cause inflammation of penis and prepuce (*balanoposthitis*). In dogs *prostatitis* is not uncommon, often together with hyperplastic lesions.

## Neoplasia

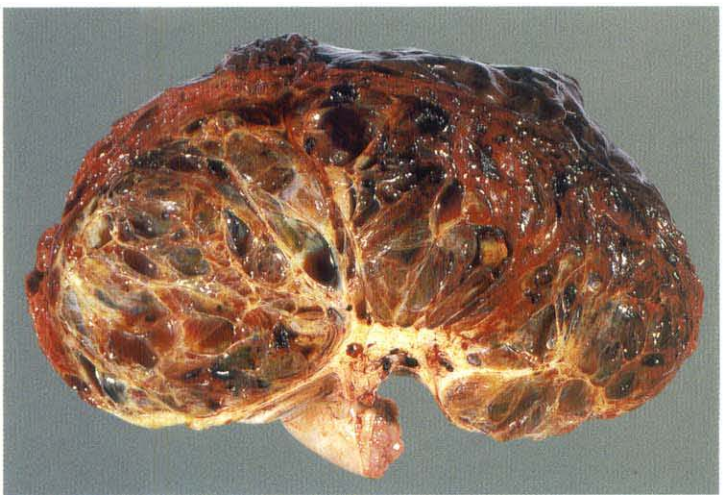
In females *neoplasms* most often occur in the ovary (mainly granulosa-theca cell tumors, sometimes sex hormone producing), uterus (mainly carcinoma and leiomyoma), vagina (fibroma), and vulva (squamous cell carcinoma).

In males neoplasms are mainly found in the testis (seminoma, Leydig cell tumor, Sertoli cell tumor), prostate gland (carcinoma) and penis (squamous cell carcinoma). Sertoli cell tumors may secrete enough estrogens to induce feminization.



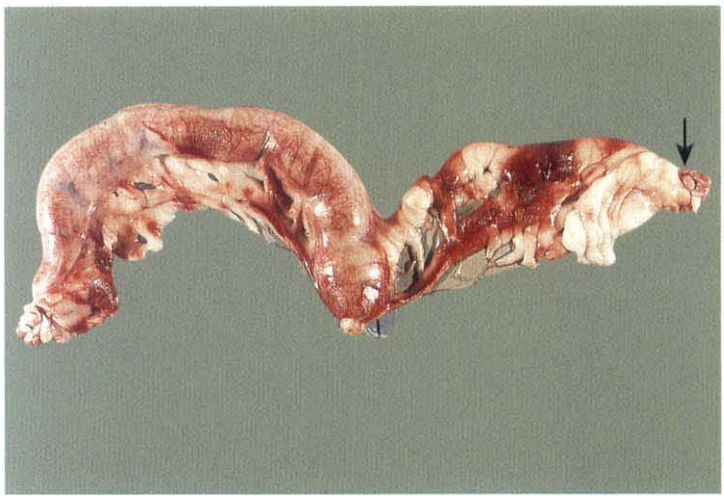
**10-1** True hermaphrodite (*hermaphroditismus ambiglandularis*)
Gonadal tissue of both sexes. Testis on the right, ovary on the left side. The uterus is partially opened to show a fetus. This is an exceptional case; true hermaphrodites are mostly sterile. Pig.

**10-2** Ovarian cysts
Multiple cysts, varying in size up to about 14 cm. They can be cystic Graafian follicles or cystic corpora lutea. Sow.

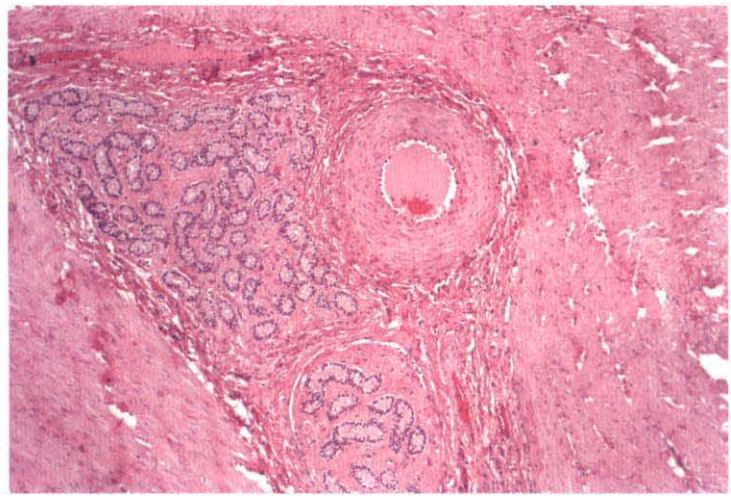


**10-3** Granulosa cell tumor
Ovary. Large (13 kg) tumor with many fluid-filled cysts and hemorrhages. Granulosa cell tumors in mares and cows are frequently large and polycystic, can produce sex steroids leading to stallion-like behaviour or nymphomania, but seldom metastasize. Horse.

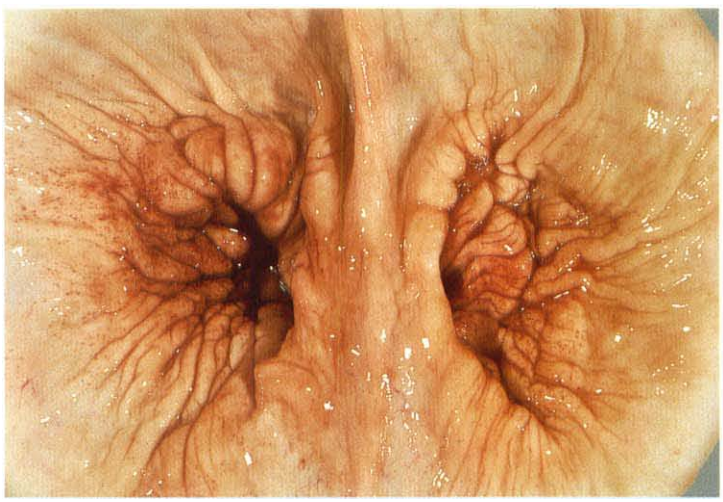
**10-4** Teratoma
Ovary, cut surface. Solid areas, as well as cystic parts containing hair. A wide variety of tissues is often present. Dog, 10 years.



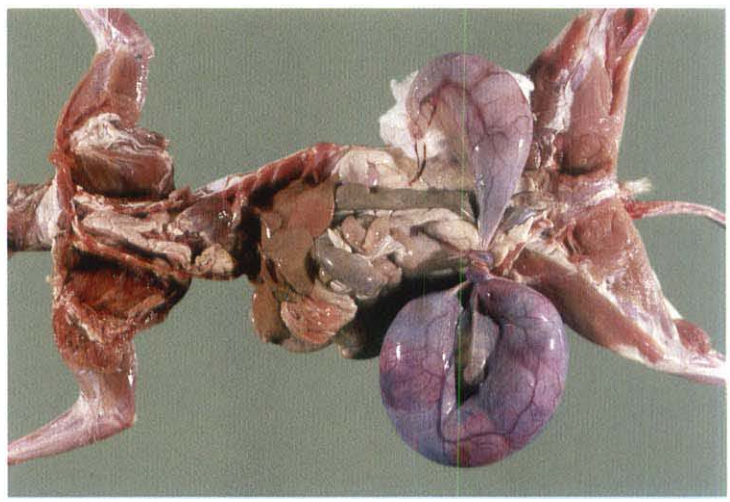
**10-5** Uterine aplasia
Aplasia of the right uterine horn. The right uterine ligament (with fatty tissue) and the right ovary (arrow) are present. Dog.



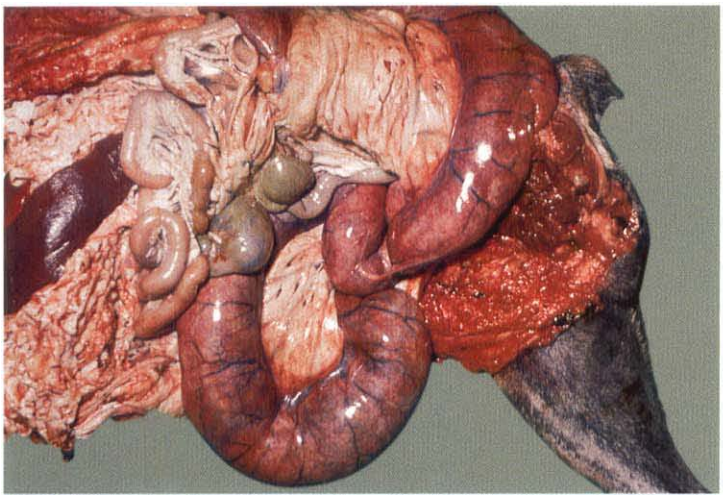
**10-6** Adenomyosis (uterine endometriosis)
Uterus. Endometrial glands and stroma in the myometrium. This may be a congenital anomaly, or due to hyperplastic overgrowth of the endometrium. Sow. HE.



**10-7** Double cervix
Persistence of the medial walls of those parts of the Müllerian ducts which develop into the cervix. Depending on the degree of persistence, an incomplete or complete double cervix occurs. Cow.

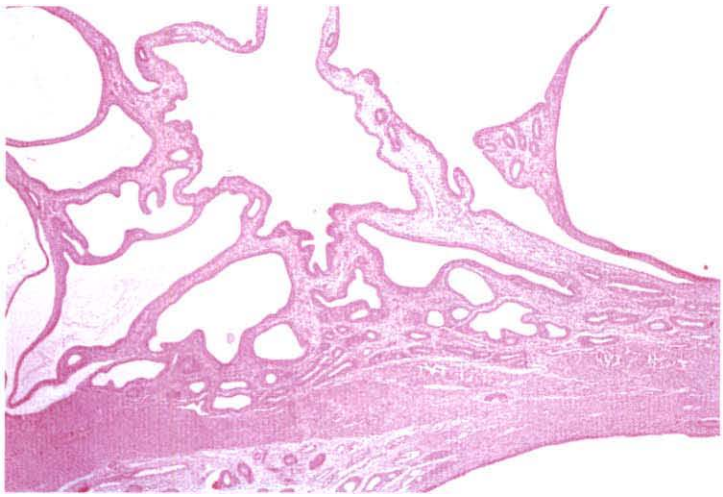


**10-8** Uterine torsion
Torsion of the pregnant right horn. The fixed points are the mesovarium and the border between uterine horn and body, resulting in passive congestion. Cat.

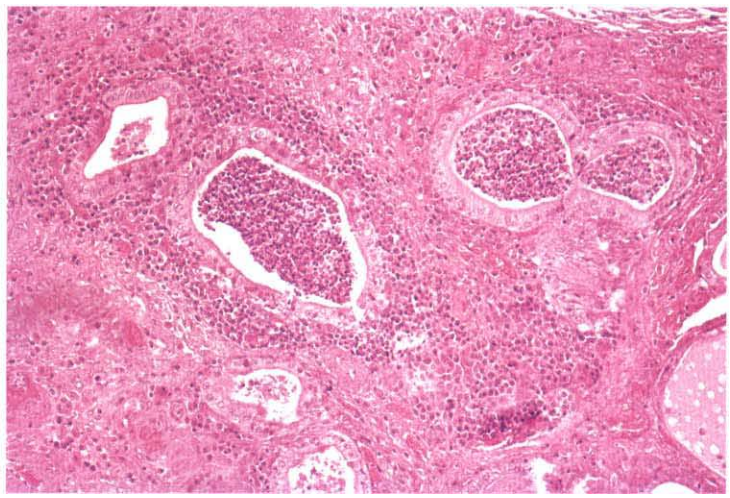


**10–9** Cystic Endometrial Hyperplasia (CEH)-pyometra complex
Uterus. Extremely distended uterine horns, containing large quantities of exudate. This disease is frequently referred to as pyometra, but the inflammatory reaction is superimposed on the CEH. In the bitch, excessive progesterone stimulation probably plays an important role in the pathogenesis of CEH. Dog.

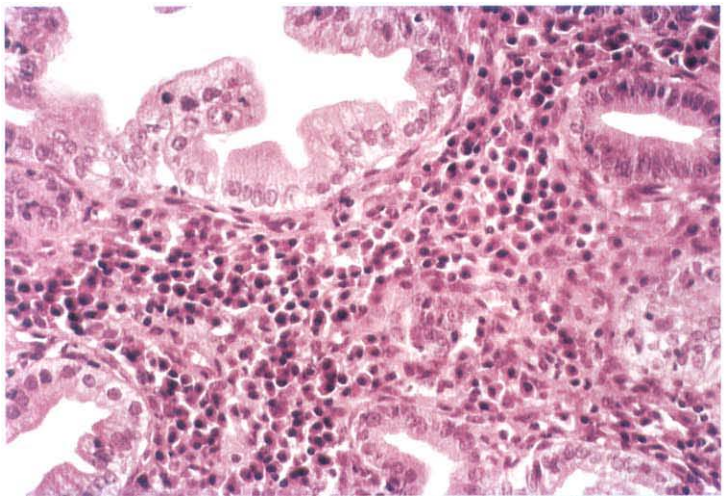
**10–10** Cystic endometrial hyperplasia (CEH)
Slightly enlarged uterus. Solid hyperplastic nodules in the endometrium as well as endometrial cysts up to approximately 5 mm in diameter. Dog.



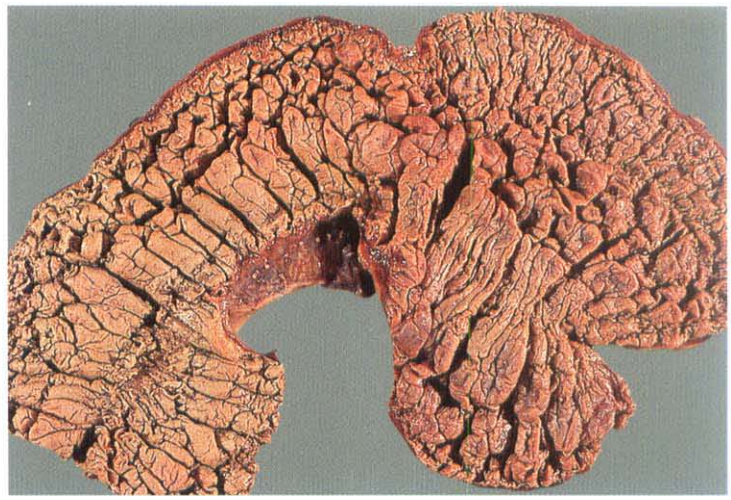
**10–11** Cystic endometrial hyperplasia (CEH)
Cystic endometrial glands. Some have papilliferous growth. Dog. HE.



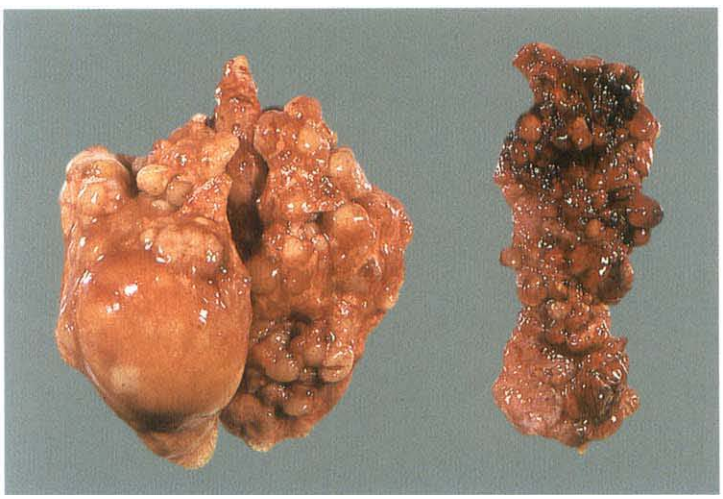
**10–12** Cystic endometrial hyperplasia (CEH)-pyometra complex
CEH with superimposed exudative and proliferative inflammatory reaction. Distended endometrial glands with tall epithelial cells and exudative as well as proliferative inflammatory cells in the endometrial stroma. Cells in the lumina of the glands are predominantly neutrophils. Dog. HE.



**10-13** Cystic endometrial hyperplasia (CEH)-pyometra complex
CEH with superimposed inflammatory reaction. Distended endometrial gland having papillary growth. There are tall epithelial cells with foamy (fatty) cytoplasm suggesting progestin induced changes. Many plasma cells in the endometrial stroma. Dog. HE.



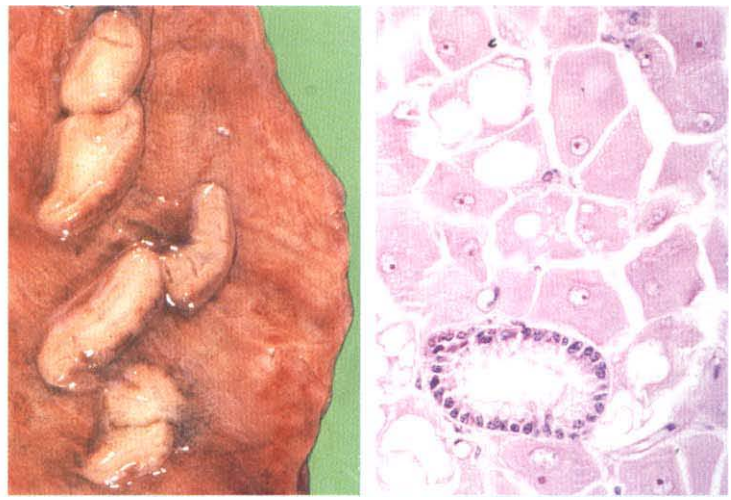
**10-14** Acute fibrino-necrotizing endometritis
Postpartum uterus. Coagulation necrosis of the superficial part of the endometrium. Redness and extensive edema below the necrotic layer. Sow.



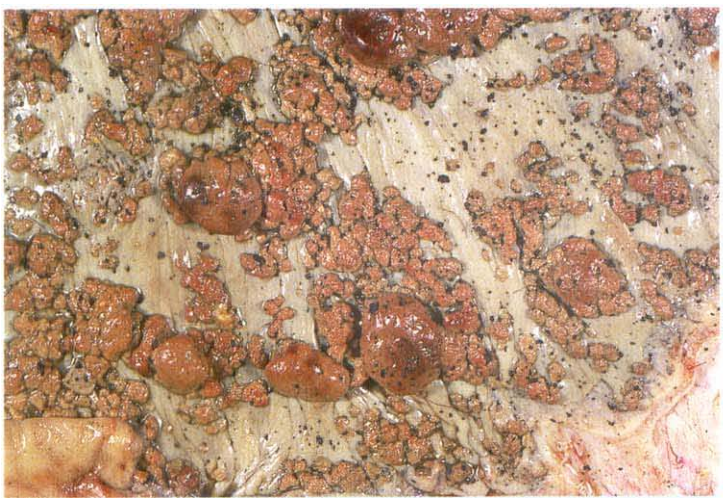
**10-15** Uterine carcinoma
Multiple carcinomas, varying in size. Histologically the tumor is an adenocarcinoma. Numerous metastases in the lungs (left). The incidence of endometrial carcinomas in rabbits is very high, especially in those over 4 years of age that have never mated. Rabbit, 5 years.

**10-16** Allantochorionic invagination
Part of the allantochorion of one fetus (left side) invaginated into the allantochorion of the other fetus. Absence of villi on the invaginated parts. Inflammation of the allantochorion on the left side. Mare.

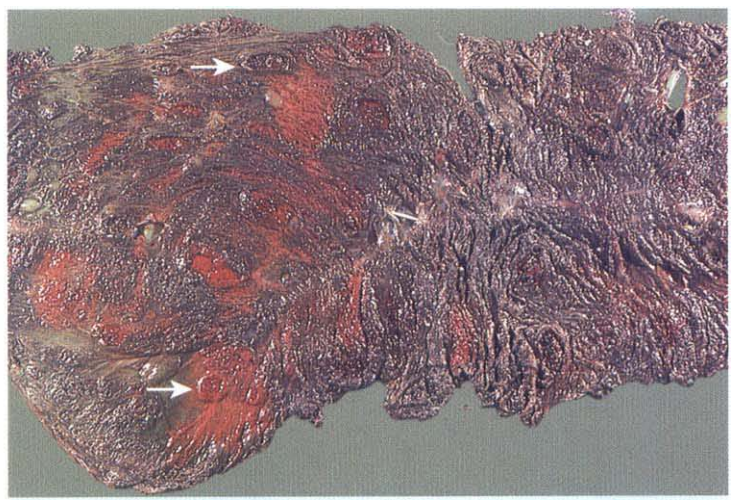
**10–17** Avillous areas on the chorion
Allantochorion, chorionic side. The occurrence of avillous areas opposite the endometrial cups (see Fig. 10–18) is normal. Equine fetus.



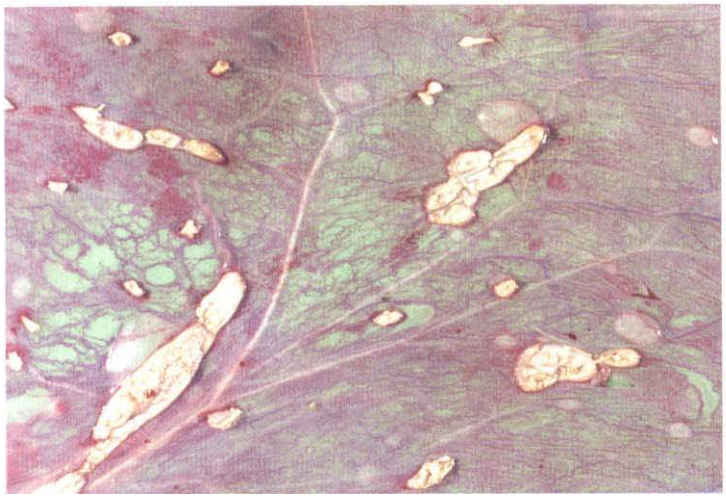
**10–18** Endometrial cups
Uterus, mucosal surface (left). Prominent oval structures, with distinct raised edges. Histologically (right, HE) they are characterized by large equine chorionic gonadotrophin (eCG)-producing cells of embryonic origin between the endometrial glands. eCG is secreted into the blood (also known as Pregnant Mare Serum Gonadotrophin, PMSG). The development of the cups starts at approximately the 35th day, and they have disappeared at about the 120th day of pregnancy. Mare.



**10–19** Adventitial placentation (*semiplacenta diffusa*)
Uterus. Development of accessory caruncles. The adventitial placentation probably represents a compensatory mechanism for an inadequate number of placentomes (see also Fig. 10–20). Cow.

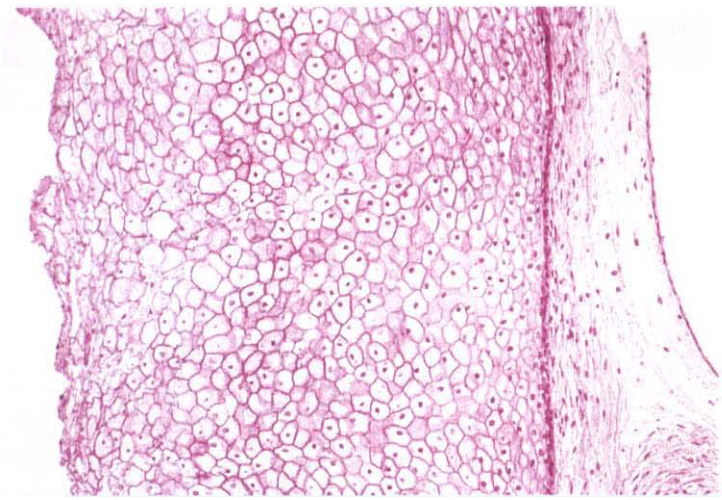


**10–20** Adventitial placentation (*semiplacenta diffusa*)
Placenta fetalis. Intercotyledonary placentation. Development of accessory cotyledons opposite accessory caruncles (see Fig. 10–19) between normal cotyledons (arrows). The red color, obvious on the left, is caused by acute inflammation. Cow.

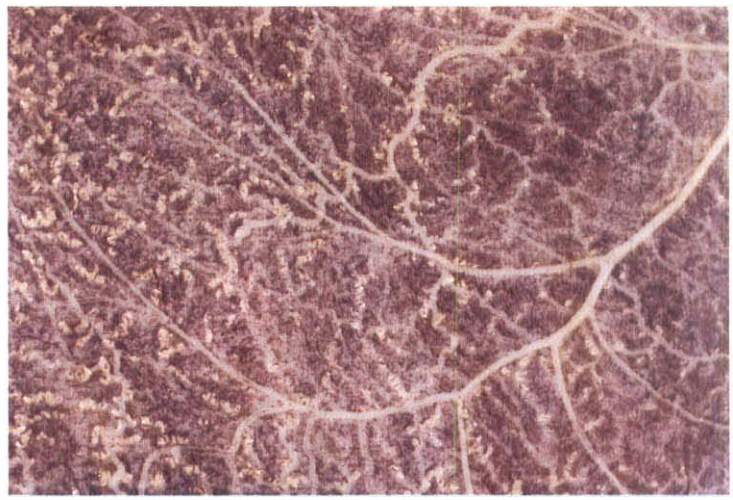


**10-21** Amniotic squamous metaplasia with cornification
Amniotic side of the allanto-amnion. White to yellow elevated spots varying in size to several centimeters. These lesions possibly represent the persistence of the amniotic plaques (see Figs. 10-22 and 10-23). Term pregnancy. Cow.

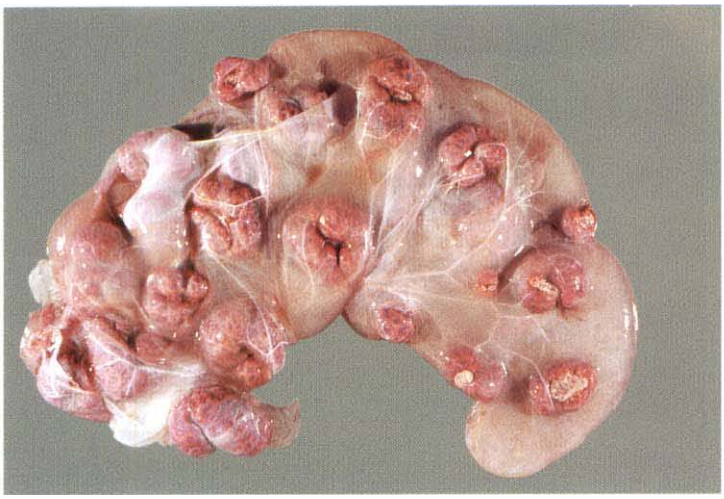
**10-22** Amniotic plaques
Amniotic side of the allanto-amnion. White to yellow plaques, approximately 2 to 10 mm in diameter. The plaques become smaller towards the end of pregnancy, and at birth most have disappeared. Amniotic plaques are normal. 7 months pregnancy. Cow.



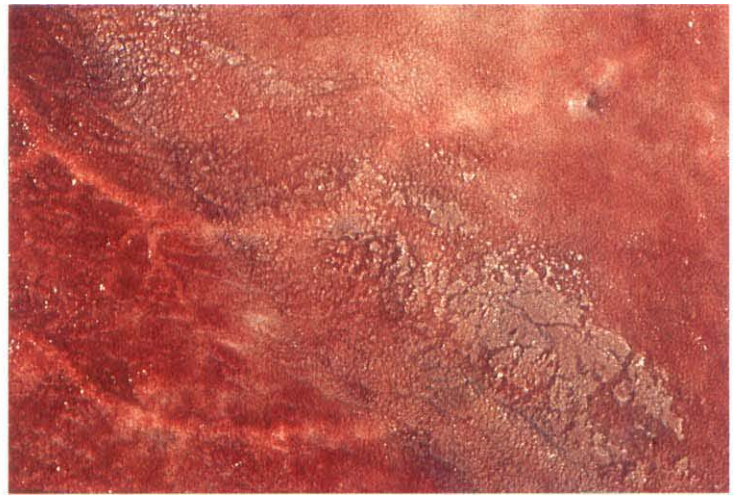
**10-23** Amniotic plaque
Many layers of cells that are characterized by distinct cell borders and small dark nuclei, mostly lying in the center of the cells. The pale cytoplasm contains glycogen. Pregnancy, 7 months. HE. Cow.



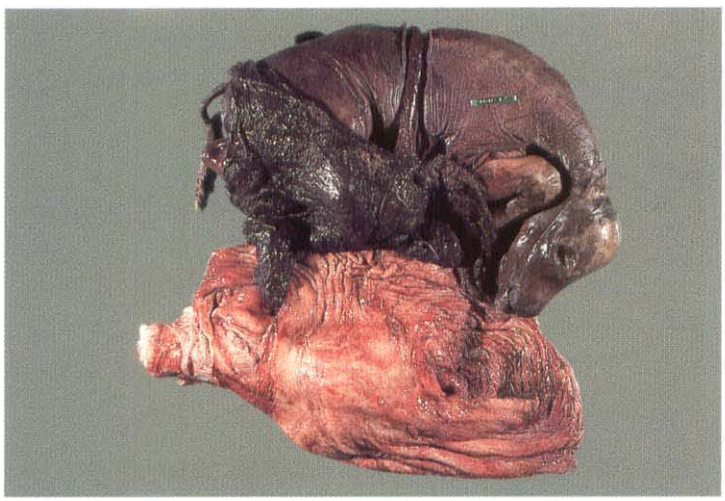
**10-24** Allantochorionic calcification
Multiple white spots due to calcium deposition. The deposits are mainly on the allantoic side and involve large parts of the allantochorionic membranes. The presence of small amounts of calcium deposits is normal in many species. Pregnancy, 7 months. Horse.



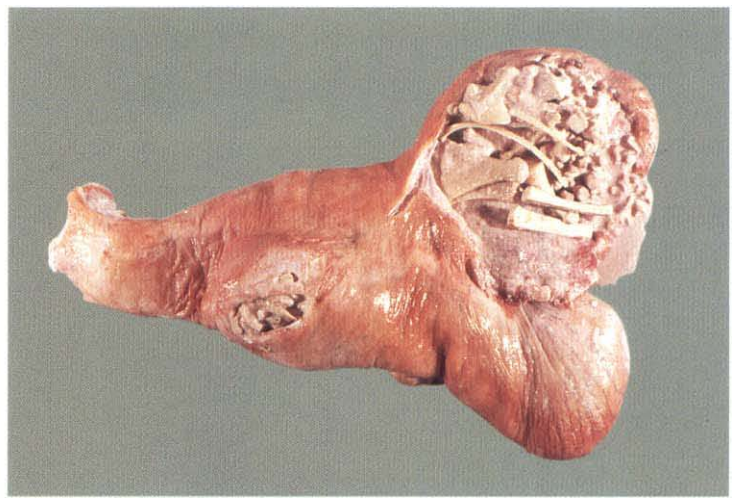
**10–25** Edema of the fetal membranes
Marked thickening of the membranes by edema in a case of hydrallantois accompanied by fetal anasarca. Pregnancy, 7 months. Cow.



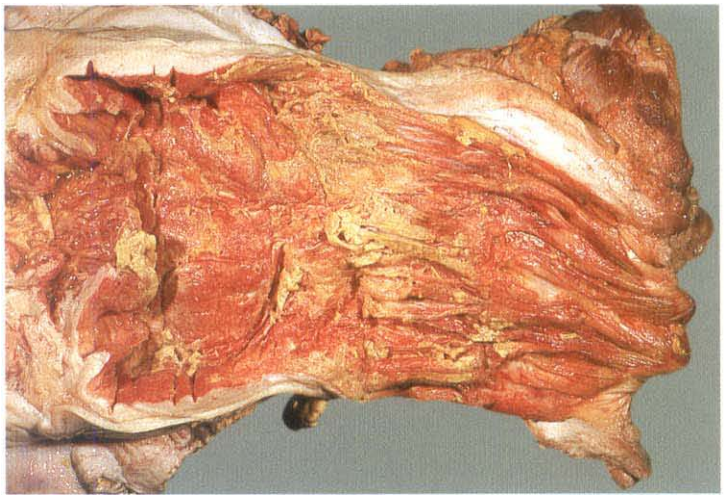
**10–26** Acute fibrino-necrotizing placentitis
Allantochorion, chorionic side. Hyperemia. Pseudomembranes consisting of fibrin and coagulation necrosis. Total or partial disappearance of chorionic villi as a consequence of necrosis (especially upper right). Equine placenta.



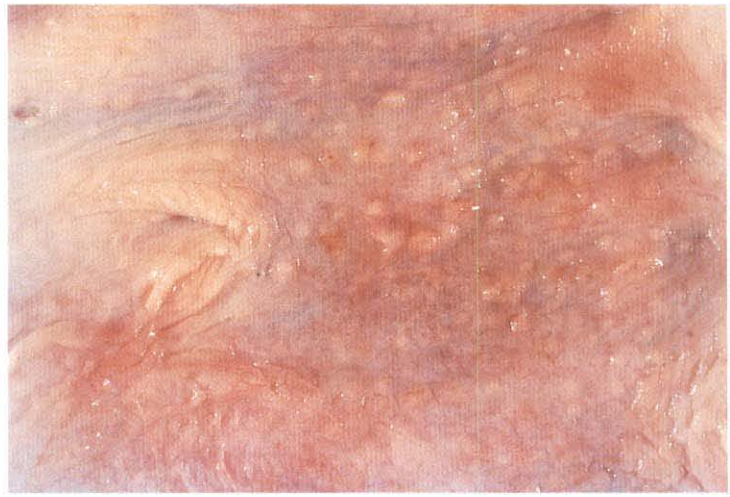
**10–27** Fetal mummification
Dry, firm, shrunken fetus. Death probably caused by strangulation by the umbilical cord. Bovine fetus.



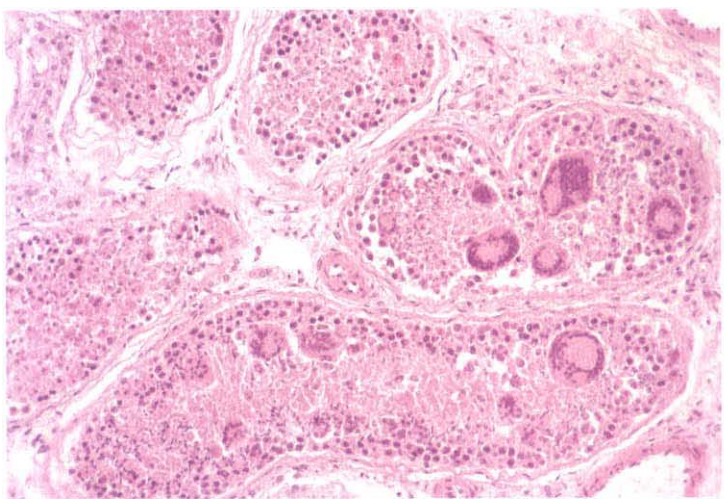
**10–28** Fetal maceration
Only the fetal bones have resisted the maceration process. Bovine fetus.



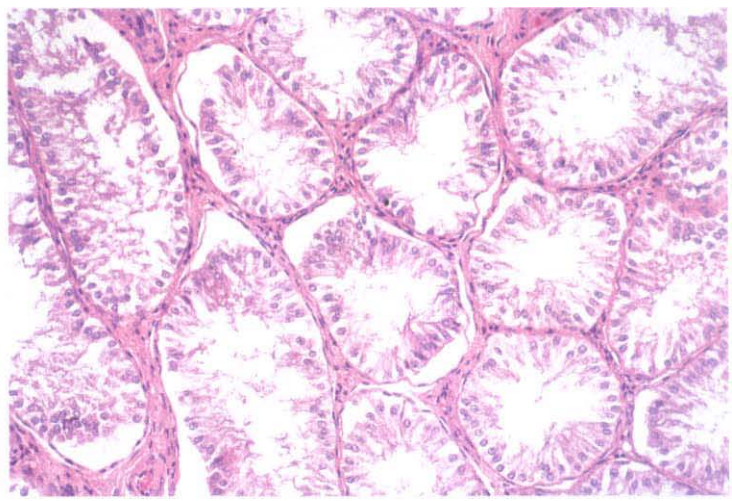
**10-29** Fibrino-necrotizing vaginitis
Vagina, mucosal surface. Hyperemia and coagulation necrosis of the mucosa. Postparturient cow.



**10-30** Granular vaginitis (follicular vaginitis)
Vestibulum vaginae. Multiple pale nodules, most of which are hyperplastic submucosal lymphoid follicles. Probably a local immunological reaction. Pig.

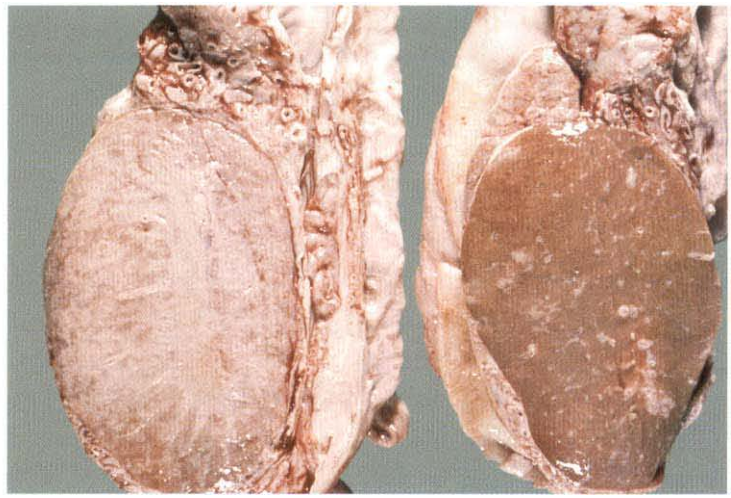


**10-31** Testicular degeneration
Nuclear pyknosis of necrotic cells. There are many multinucleated giant cells in the lumen of the seminiferous tubules, probably formed by fusion of degenerated spermatogenic cells. Dog. HE.



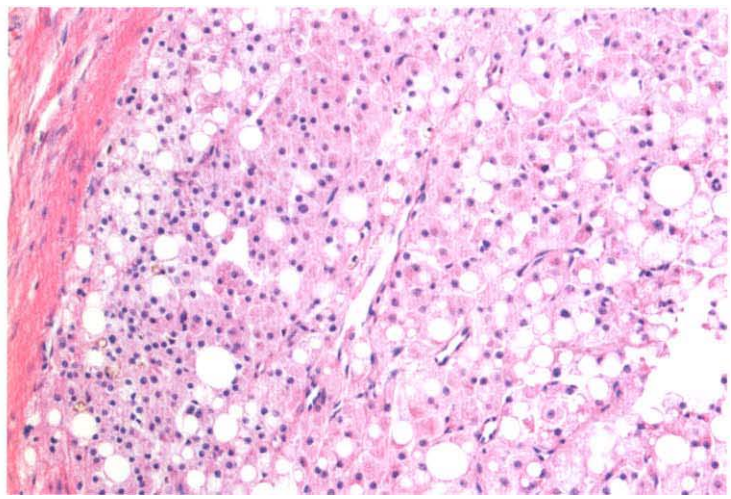
**10-32** Abdominal cryptorchidism
Testis. Seminiferous tubules lacking spermatogenic epithelium are completely lined with tall Sertoli cells. The cooler environment of the scrotal sac is probably necessary for normal epithelial development and spermatogenesis. Dog. HE.

**10–33** Torsion of the spermatic cord
Passive congestion, hemorrhage and edema of the spermatic cord, epididymis and the testis. Most cases occur in abdominal cryptorchids as in this specimen. Boar.

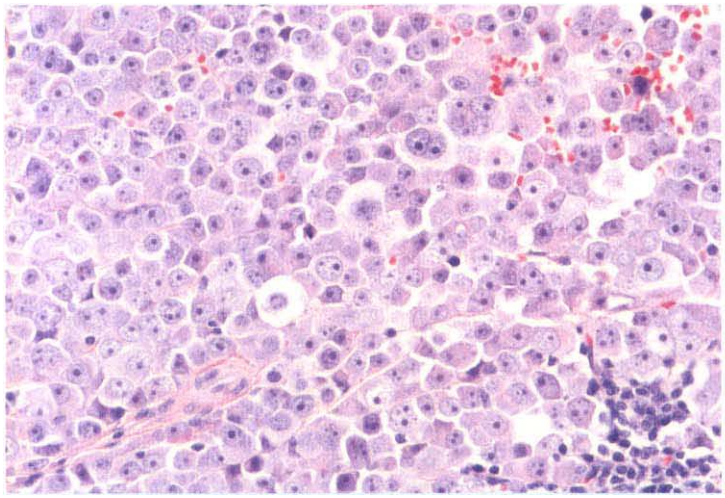


**10–34** Fibrotic testis
Cut surfaces of fibrotic (left) testis. Small, pale, firm with white areas, predominantly consisting of fibrous tissue. Right testis is normal. Bull.

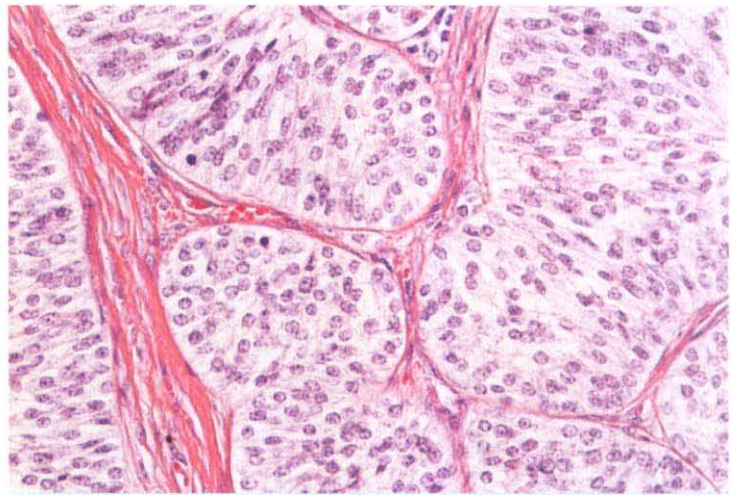
**10–35** Leydig cell tumor (interstitial cell tumor of the testis)
Testis. Many Leydig cell tumors are characterized by the yellow color and the hemorrhages in the tumor. Dog



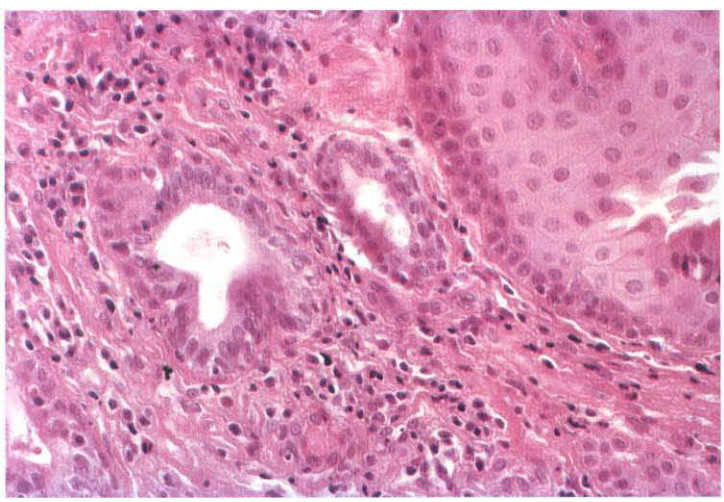
**10–36** Leydig cell tumor (interstitial cell tumor of the testis)
Large round or polyhedral tumor cells with abundant vacuolated cytoplasm; scanty stroma. Seldom malignant. The differentiation between hyperplasia and a benign tumor of Leydig cells is arbitrary. Dog. HE.



**10-37** Seminoma
Testis. Solid tumor replacing seminiferous tubules, composed of large polyhedral cells with prominent nucleoli resembling spermatogenic cells. Scanty stroma. Lymphoid accumulation at right. Dog. HE.

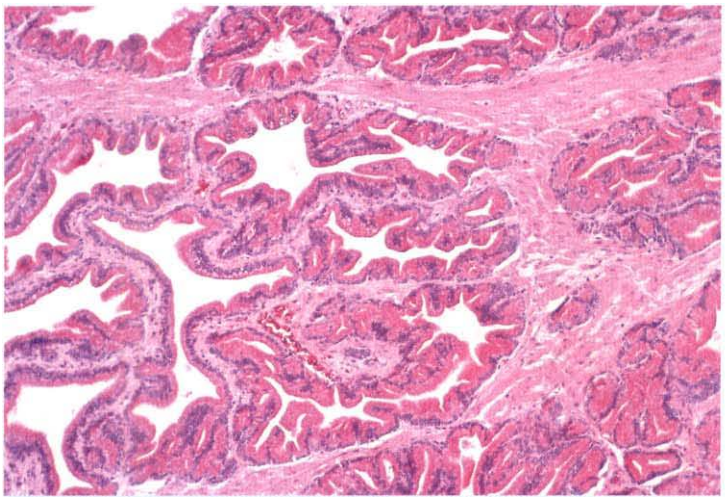


**10-38** Sertoli cell tumor
Testis. Distended tubules with solid, elongated and palisading, tumor cells having pale cytoplasm separated by thick bands of partially hyalinized fibrous tissue. Dog. HE.

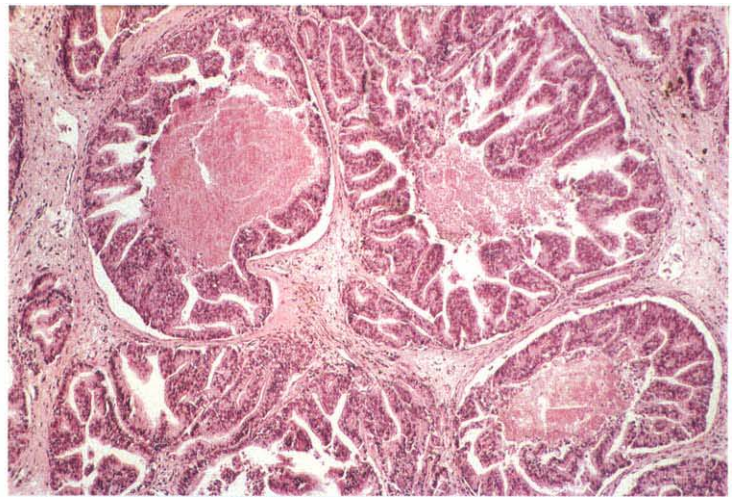


**10-39** Prostatic squamous metaplasia
Prostate. Squamous metaplasia of glandular epithelium (right side). This metaplasia starts as a hyperplasia of 'basal cells' ('reserve cells') between the glandular epithelium and the basement membrane (left tubule), followed by disappearance and replacement of the original glandular epithelium. The histogenesis of metaplasia as described above is called indirect metaplasia or prosoplasia. Dog with a Sertoli cell tumor accompanied by hyperestrogenism. HE.

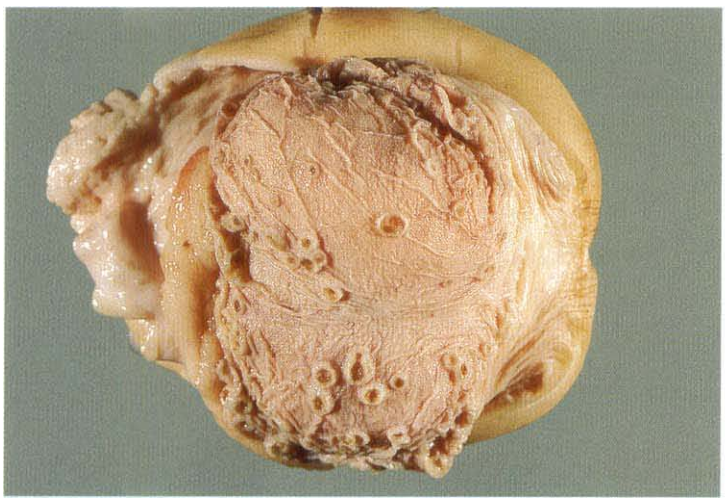
**10-40** Prostatic hyperplasia
Symmetrical prostate enlargement, with the surface irregularly nodular. Urinary bladder (left), urethra (right). Dog.



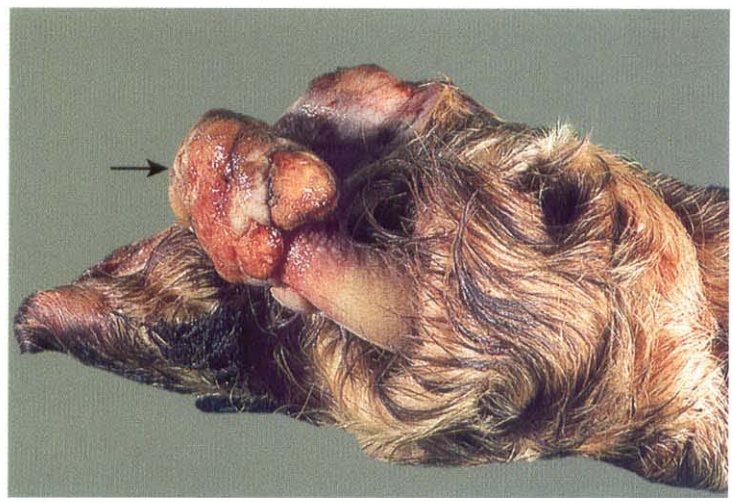
**10-41** Prostatic hyperplasia and hypertrophy
Diffuse hyperplasia characterized by tall epithelium and papillary growth into the lumen. Some cystic glands as well as broad sheets of hyperplastic fibromuscular tissue. Dog. HE.



**10-42** Prostatic adenocarcinoma, alveolar papillary type
Papillary growth of epithelium into alveolar-like spaces, which are surrounded by bands of connective tissue. The spaces are almost completely filled with tumor cells and necrosis. Dog. HE.



**10-43** Ulcers in preputial diventiculum
Preputial diverticulum. Multiple plaques, varying in size up to 10 mm and consisting of hyper- and parakeratotic epithelium (leukoplakia) with ulceration in the center of the plaques. A boar with these lesions can be a source for infection of gills with *Actinobaculum suis* (formerly *Corynebacterium* or *Eubacterium suis*), which may induce pyelonphritis. Boar.



**10-44** Fibropapilloma on the glans penis
Firm tumor with a cauliflower-like growth on the glans penis (arrow). This tumor is probably caused by the virus that causes bovine cutaneous papillomas. Bull.

Chapter 11

# The nervous system



## THE NERVOUS SYSTEM

The nervous system includes the central nervous system (brain and spinal cord), and the peripheral nerves.

The most common lesions of the central nervous system consist of:

- congenital anomalies;
- cytopathological changes;
- demyelination;
- malacia;
- circulatory disturbances;
- inflammation;
- traumatic injury; and
- neoplasia.

### *Congenital anomalies*

*Malformations* of the central nervous system are relatively common in domestic animals. A large proportion of these malformations are developmental defects with a gross morphological appearance, either inherited or caused by *in utero* exposure to certain viral agents. Malformations as a consequence of these viruses include *hypoplasia* following destruction of progenitor cells and *atrophy* following destruction of already differentiated growing tissue.

Other developmental defects may result from a primary functional lesion, for example those which arise as a consequence of inherited biochemical disturbances (such as the *lysosomal storage diseases*), and some remain unexplained.

## Cytopathological changes

The central nervous system (CNS) has unique populations of cells (neurons, neuroglia, microglia and choroid plexus cells) and the terminology used to describe cytopathological changes in these cellular elements is generally not applicable to other tissues. These constituent cells vary in their susceptibility to injury with neurons being the most sensitive.

### Neurons

Distinctive changes in *neurons* include:

- *central chromatolysis* in response to axonal injury and prolonged stimulation of axons (also referred to as the axonal reaction);
- *ischemic cell change* following ischemia and other injurious influences;
- cytoplasmic accumulation of metabolic products typical for *(lysosomal) storage diseases*; and
- deposition of *lipofuscin pigment* related to aging.

Fragments of necrotic neurons may be removed by fixed macrophages (microglia) in a process referred to as *neuronophagia*.

Intranuclear or intracytoplasmic *inclusion bodies* may be present in neurons, for instance in certain viral infections. *Cytoplasmic vacuolation of neurons* is a feature of the spongiform encephalopathies such as scrapie and bovine spongiform encephalopathy (BSE).

### Glial cells

*Glial cells* (astrocytes, oligodendrocytes, ependymal cells and microglial cells) are more resistant to injury than neurons.

- Astrocytes may undergo hypertrophy *(reactive astrogliosis)* or proliferation *(astrocytosis)*, in longstanding lesions resulting in a *fibrillary gliosis or glial scar*.
- In chronic degenerative conditions, astrocytes with abundant pink cytoplasm and eccentric nuclei termed *gemistocytic astrocytes* or *gemistocytes* may be observed.
- *Oligodendroglia* may exhibit degeneration or proliferation.
- Perineuronal oligodendroglia may hypertrophy and proliferate in a process referred to as *satellitosis*.
- Responses of *ependymal cells* to injury include atrophy, degeneration and necrosis.
- The mesoderm derived sessile *microglia*, in response to injury, may react by activation (rod cells) and proliferation. Microglial proliferation may be focal, forming a *glial nodule* to remove a tiny focus of necrosis or a dead neuron, or be diffuse.
- Blood-born *macrophages*, functionally comparable to microglia, may accumulate in the CNS in response to injury, mostly necrosis. They may have a typical foamy lipid-laden cytoplasm due to ingested myelin debris, often referred to as *gitter cells*.

## Demyelination

A number of conditions primarily involves CNS myelin and may be manifest by a reduced quantity and/or quality of myelin. They include disorders of myelin synthesis and maintenance resulting in the formation of abnormal myelin (the *leukodystrophies*) or a diminished quantity of myelin (*hypomyelination diseases*). Many of these diseases have a hereditary metabolic basis.

Other changes involving myelin include *vacuolization of myelin* (such as in spongy degeneration) and destruction of myelin or myelin-forming cells in *demyelinating diseases*.

Demyelination refers to destruction of a normally formed myelin sheath and may be primary or secondary.

- *Primary demyelination*, characterized by selective destruction of the myelin sheath with an intact axon, is rather uncommon in domestic animals and associated with a few viruses such as canine distemper virus.
- Much more common is *secondary demyelination* (*Wallerian degeneration*) where the loss of myelin is a consequence of axonal degeneration. A local lesion of the axon results in degeneration of axon and myelin distal to the point of injury of the nerve. The focal ovoid or round eosinophilic distentions of these axons are referred to as *spheroids*.

## Malacia

*Malacia* means softening and is used to describe liquefaction necrosis of central nervous tissue.

## Circulatory disturbances

### Edema

Edema of the CNS can be distinguished in *vasogenic* and *cytotoxic edema*. The accumulation of fluid may occur extracellularly, resulting from increased vascular permeability and referred to as vasogenic edema, or intracellularly with normal vascular permeability and referred to as cytotoxic edema. Injury to the CNS may cause both vasogenic and cytotoxic edema concurrently.

- *Vasogenic edema* predominantly affects the white matter and is recognized adjacent to hematomas, contusions, infarcts, inflammatory foci and neoplasms or may be seen in certain toxicities.
- *Cytotoxic edema* is often due to ischemia and/or hypoxia in which both the gray and white matter of the brain may be affected.

### Infarction

The gross appearance of the infarction may differ according to the pathogenesis.

- Infarction after complete occlusion of an artery causes ischemic necrosis (bland or *pale infarction*).
- Partial occlusion or reperfusion of an ischemic infarction is responsible for abnormal permeability of the wall of vessels and seeping out of blood into the infarct. Thus it is referred to as *hemorrhagic infarction*.

Infarction involving the gray matter tends to be hemorrhagic whereas infarction of the white matter is often pale. Areas of infarction eventually become soft because of liquefaction necrosis.

## Inflammation

The most common histological features of *inflammation* of the CNS comprise:

- perivascular cuffing;
- gliosis; and
- neuronal degeneration.

The nature of the inflammatory infiltrate may vary according to the etiology but the following simplified guidelines are applicable to inflammation caused by infectious agents.

- Polymorphonuclear cells predominate in bacterial infections.
- Lymphocytes are the main cell type in virus-induced conditions with lesser numbers of plasma cells and macrophages.
- Granulomatous inflammation is seen in infections due to fungi, protozoa, parasites and some intracellular bacteria (for example *Mycobacterium* species).

Lesions that may accompany the *encephalomyelitis* include meningitis, ganglioneuritis, vasculitis, necrosis and demyelination.

*Meningitis* concerns the leptomeninges (the pia mater, subarachnoid space and adjacent arachnoid mater) and/or the dura mater (referred to as pachymeningitis). Pathological processes that initially involve the meninges, most commonly the leptomeninges, can secondarily invade the nervous tissue. On the other hand, processes that primarily affect the nervous tissue can secondarily affect the (lepto)meninges. Leptomeningitis can be acute, subacute or chronic and, depending on the cause, the inflammation may be primarily purulent, mononuclear or granulomatous as described above.

## Traumatic injury

Blunt trauma to the brain may result in *concussion*, usually not associated with gross lesions, or *contusion*, characterized by focal brain injury that is grossly detectable, usually as hemorrhage.

Spinal cord trauma can involve concussion, contusion, *laceration* (with disruption of the architecture of the tissue), *transection*, and *compression* (for example in cervical stenotic myelopathy).

## Neoplasia

Primary *neoplasms* of the CNS are most common in the dog and cat. These include neoplasms of:

- neuronal cells;
- neuroglial cells;
- choroid plexus; and
- mesodermal tissue.

Meningioma is the most common.

## Peripheral nervous system

A significant number of conditions affecting the CNS may also cause lesions in the *peripheral nervous system* (PNS) which is explained by injury to neuron cell bodies residing in the CNS or because the PNS is equally vulnerable to the condition. For example, in certain viral or protozoal infections concurrent inflammation in the CNS and PNS may occur.

Inflammation of the PNS may include:

- *(poly)radiculoneuritis* (implying inflammation of peripheral nerves and spinal nerve rootlets); and
- *ganglionitis* (inflammation of spinal ganglia).

Congenital anomalies and disorders of myelin formation and maintenance in the PNS are rarely seen.

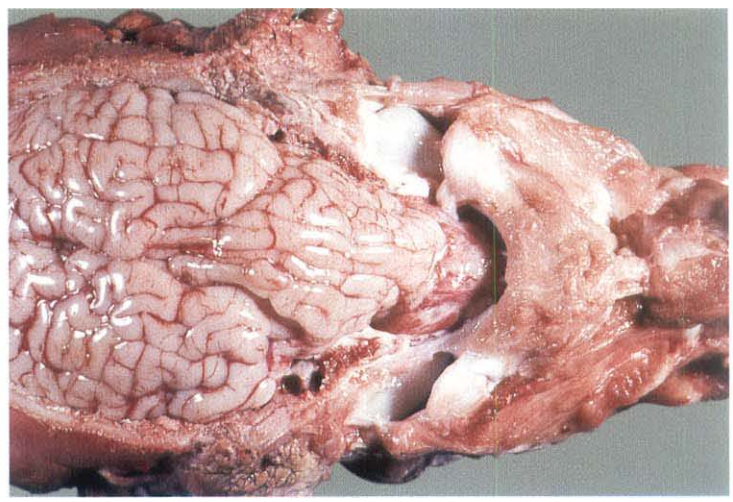
The reaction pattern following traumatic injury to peripheral nerves is similar to that described in the CNS and may include *Wallerian degeneration* distal to the point of injury of the nerve.

Primary *neoplasms* of the PNS are uncommon and mostly reported in dogs and cattle. Most of them are derived from the peripheral nerve sheath (mostly Schwannoma).

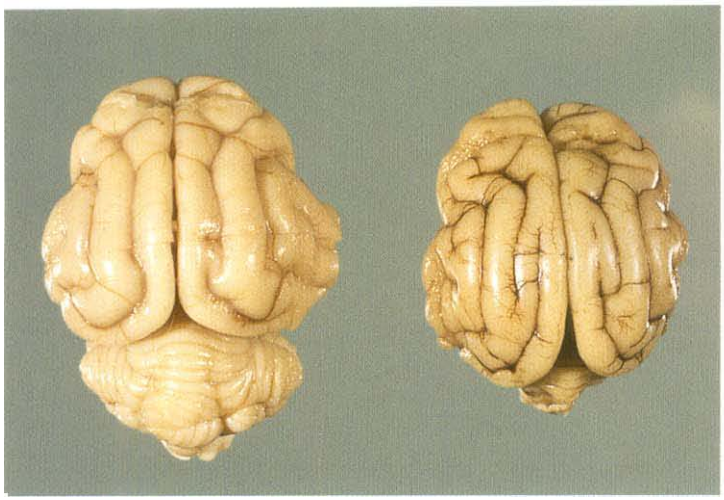
**11-1** Internal hydrocephalus
Brain, transverse section through diencephalon. Severe dilation of the ventricular system causing atrophy of neural parenchyma. Hydrocephalus may be congenital or acquired and in the dog it may often result from obstruction to the flow of cerebrospinal fluid. Dog.

**11-2** Cranium bifidum with meningoencephalocele
Protrusion of a large fluid filled hernial sac of meninges and brain tissue through a defect in the skull. The sac is covered with skin of the forehead. Piglet.

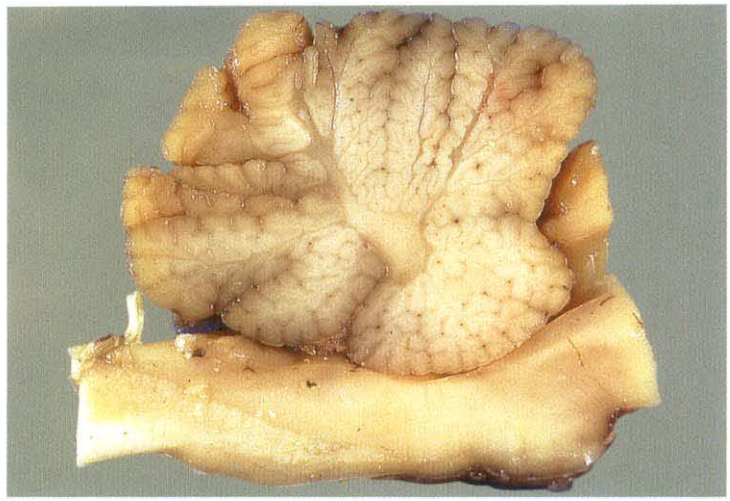
**11-3** Spina bifida aperta
Lumbosacral region. Soft, well vascularized mass of neural tissue directly exposed to the exterior. Anomaly represents a closure defect of neural tube with failure of separation from ectoderm and defective induction of skeletal investment. Piglet.



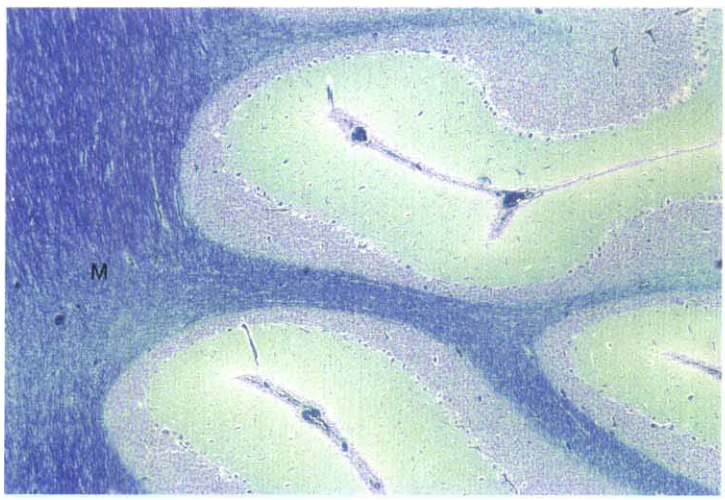
**11-4** Arnold-Chiari malformation
Displacement of brain in caudal direction due to undersized cranial cavity. Protrusion of hemispheres into the posterior fossa (note V-shaped impression of tentorium cerebelli) and coning of cerebellum and caudal brainstem into foramen magnum. Calf.



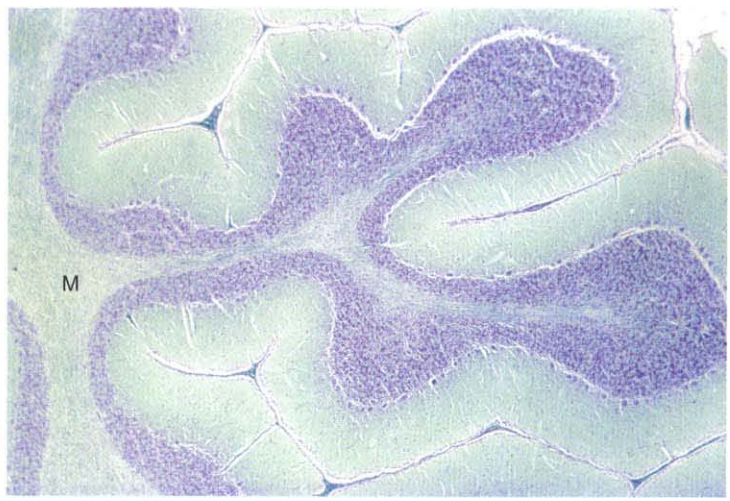
**11-5** Cerebellar hypoplasia
Markedly smaller cerebellum (right) in comparison with normal (left). Hypoplasia due to interference of normal development by selective destruction of external germinal layer by the panleukopenia virus during perinatal growth. Kitten.



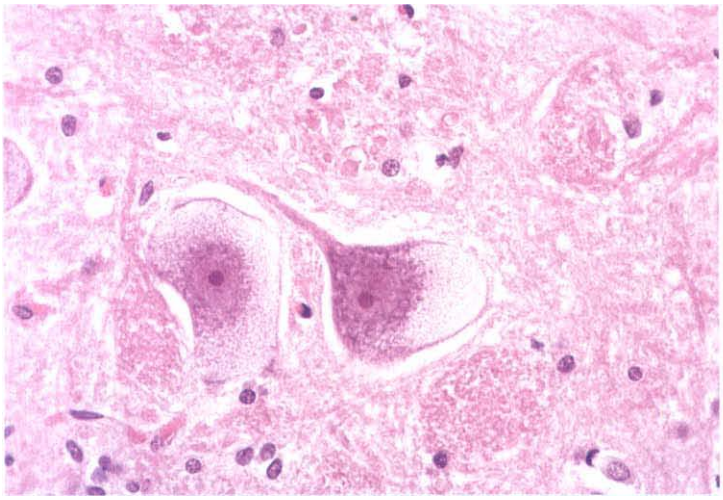
**11-6** Hypomyelination
Cross section through cerebellum and medulla oblongata. White matter not visible due to paucity of myelin. β-Mannosidosis. Newborn calf.



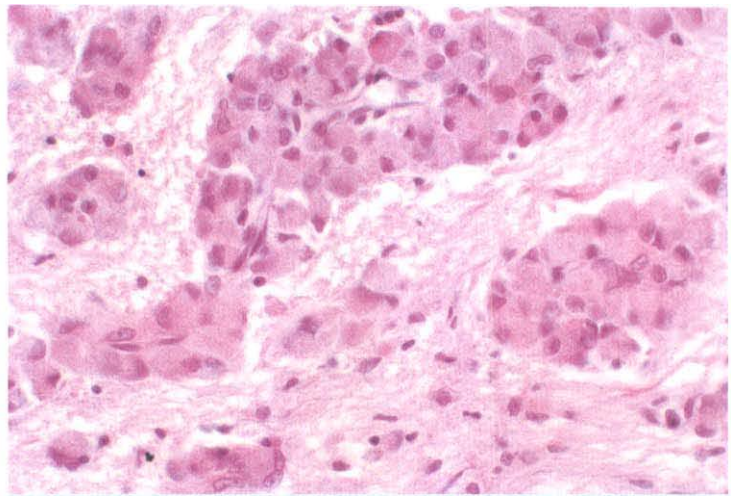

**11-7** Normal cerebellum
Portion of cerebellum showing normal myelin staining of white matter (M). Newborn calf. Kluver Barrera stain for myelin.



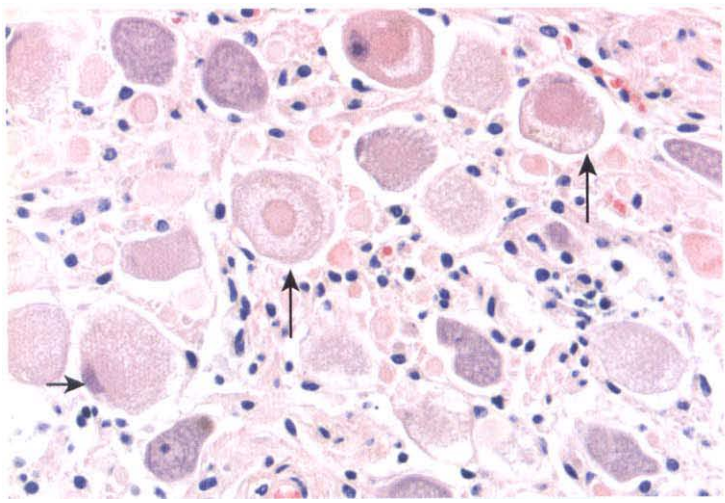

**11-8** Hypomyelination
Deficiency of myelin due to hypomyelination in the cerebellar white matter. There is reduced staining for myelin (M) when compared to cerebellum of control calf (see Fig. 11-7). Intrauterine bovine viral diarrhea virus (BVDV) infection. Newborn calf. Kluver Barrera stain for myelin.



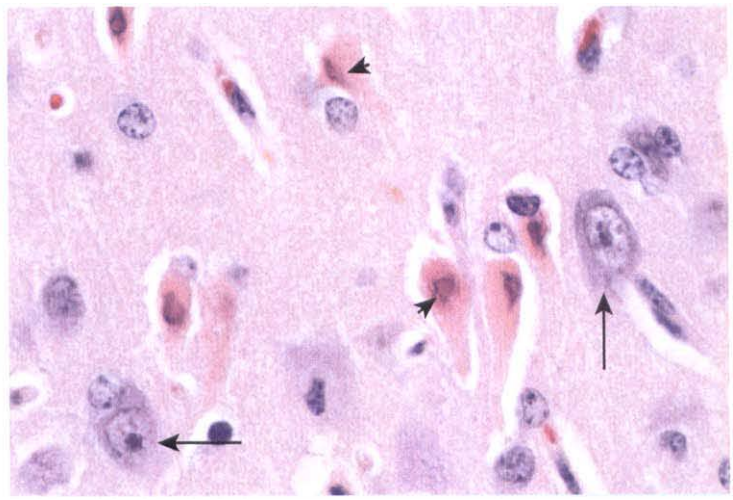
**11-9** Glycogenosis
Olivary nucleus. Reticulation of the cytoplasm of neuronal cells due to glycogen storage, caused by a metabolic error of lysosomal catabolism. Glycogenosis type II. Lapland dog. HE.



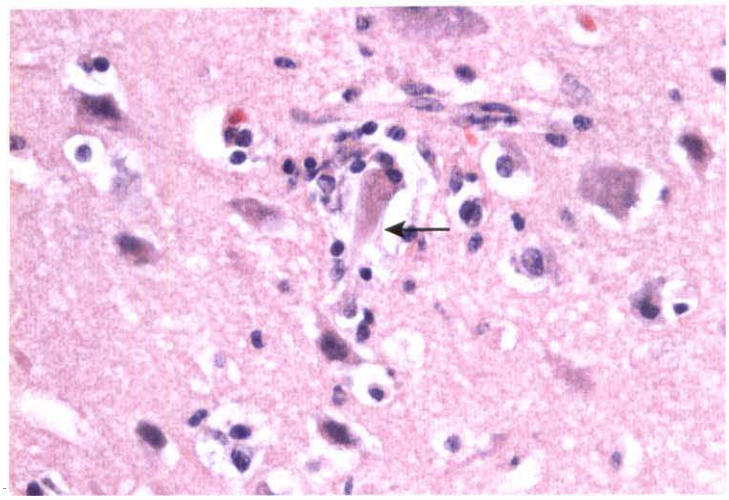
**11-10** Globoid cell leukodystrophy
Cerebral white matter. Loss of myelin and perivascular accumulations of characteristic (PAS-positive) cells with large cell bodies and mostly eccentric nuclei. These cells are of histiocytic origin and have accumulated β-galactocerebroside. West Highland White terrier dog. HE.



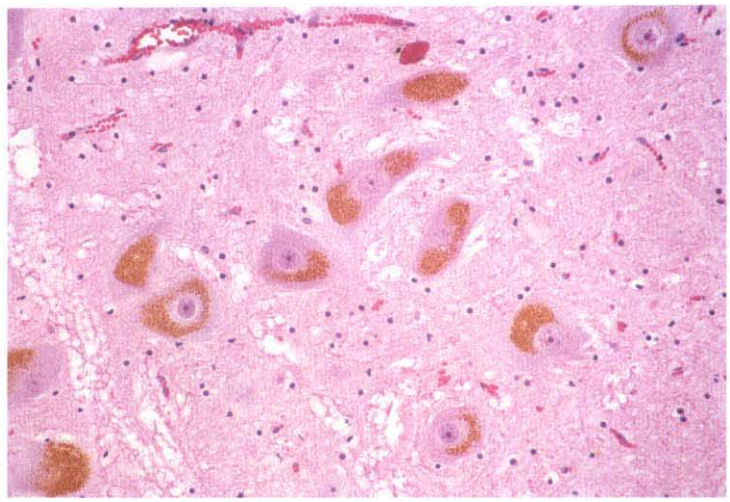
**11-11** Neuronal chromatolysis
Spinal ganglion. Several neurons are swollen with peripheral displacement of the nuclei (short arrow), the cytoplasm stains lightly eosinophilic due to disappearance of Nissl substance and can be finely vacuolated. In addition to these characteristics of chromatolysis, some neurons contain central, deeply eosinophilic 'inclusions' (long arrows) as seen in grass sickness (dysautonomy). Horse. HE.



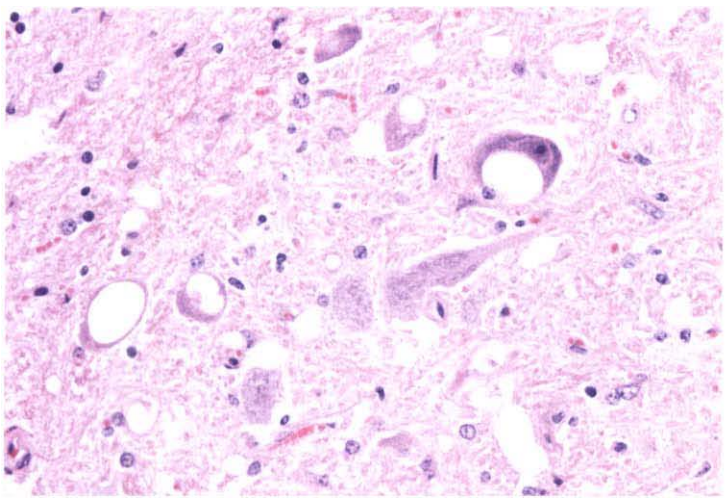
**11-12** Ischemic cell change
Cerebral cortex. Acute neuronal necrosis due to hypoxia. Affected neurons are shrunken, have eosinophilic cytoplasm and hyperchromatic or pyknotic nuclei (arrowheads) contrasting with normal neurons (arrows). Newborn calf. HE.



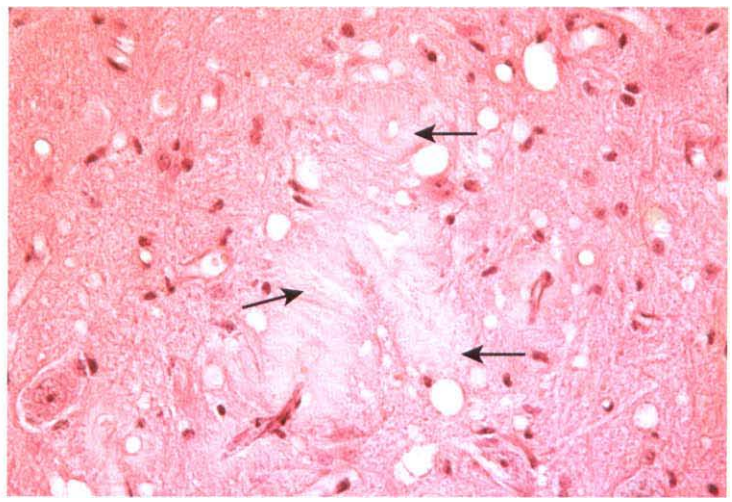
**11-13** Neuronophagia
Cerebral cortex. Necrotic neuronal cell body (arrow) surrounded and invaded by hypertrophic microglial cells. Process of phagocytic removal especially seen in viral polioencephalomyelitis. Distemper. Dog. HE.



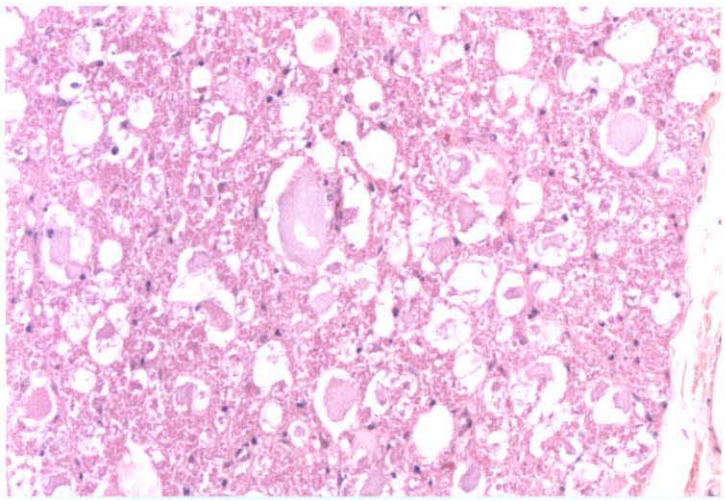
**11-14** Neuronal pigmentation
Midbrain. Accumulation of yellowish brown pigment resembling ceroid and lipofuscin in neuronal cell bodies. Neuronal ceroid-lipofuscinosis. Sheep. HE.



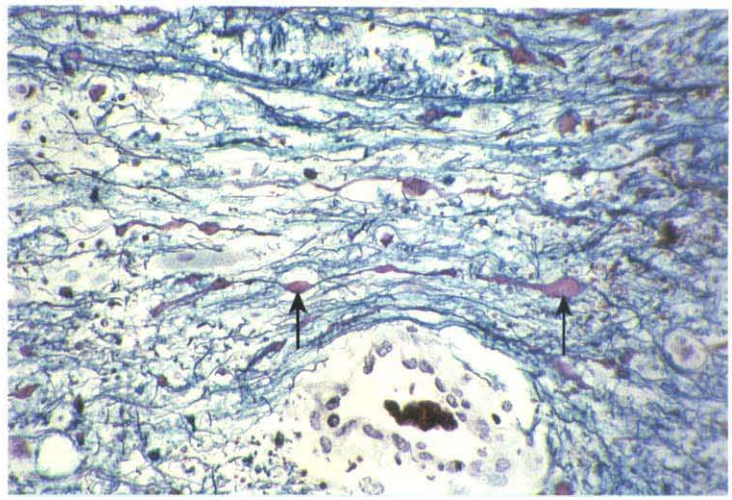
**11-15** Spongiform encephalopathy
Medulla oblongata. Well delineated empty vacuoles in the cytoplasm of neurons and in the neuropil; characteristic for the spongiform encephalopathies such as scrapie, bovine spongiform encephalopathy (BSE) and feline spongiform encephalopathy (FSE). Scrapie. Sheep. HE.



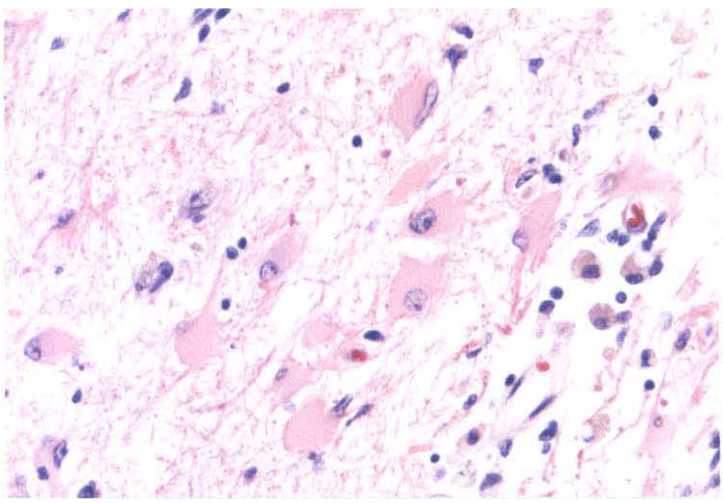
**11-16** Cerebrovascular amyloid
Cerebrum. Pale eosinophilic amorphous material (arrows) consistent with amyloid deposition associated with blood vessels. Scrapie. Sheep. HE.



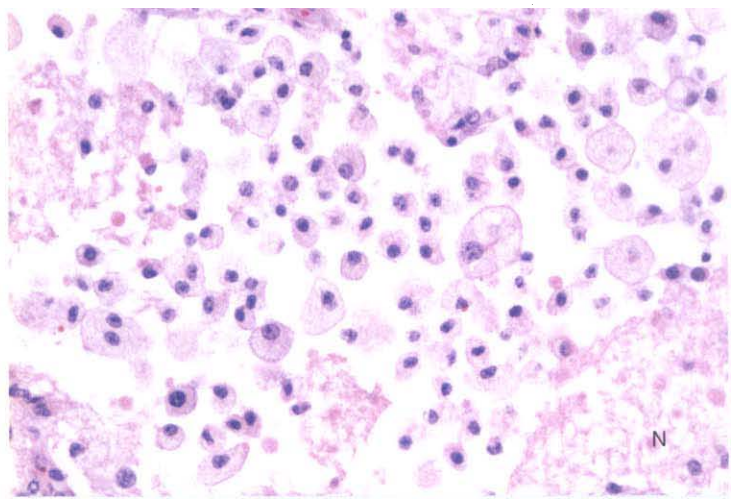
**11-17** Axonal swelling
Spinal cord white matter, transverse section. Multiple eosinophilic swollen axons (spheroids) within distended myelin sheaths. Spheroid formation is possibly due to a blockade of axoplasmic flow and is often seen in acute injury associated with mechanical trauma and vascular lesions. Spinal cord compression. Horse. HE.



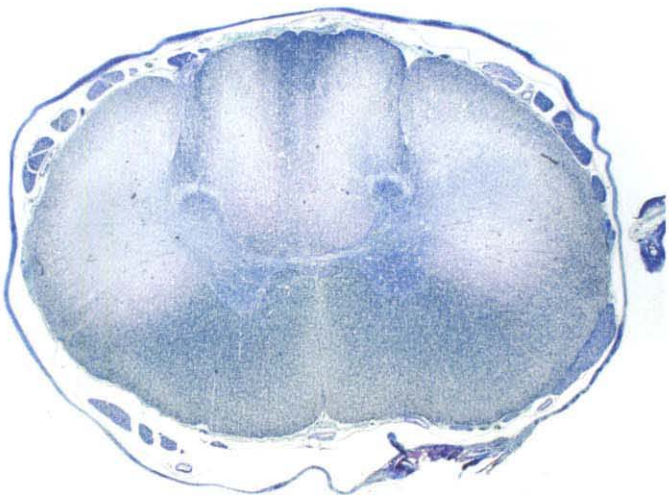
**11-18** Axonal swelling
Cerebellar peduncle. Globular and fusiform axonal swellings (spheroids; arrows) adjacent to an area of malacia (not shown on picture – see Fig. 11-28). Focal symmetrical encephalomalacia. Sheep. Luxol fast blue-Holmes stain for myelin and axons, respectively.



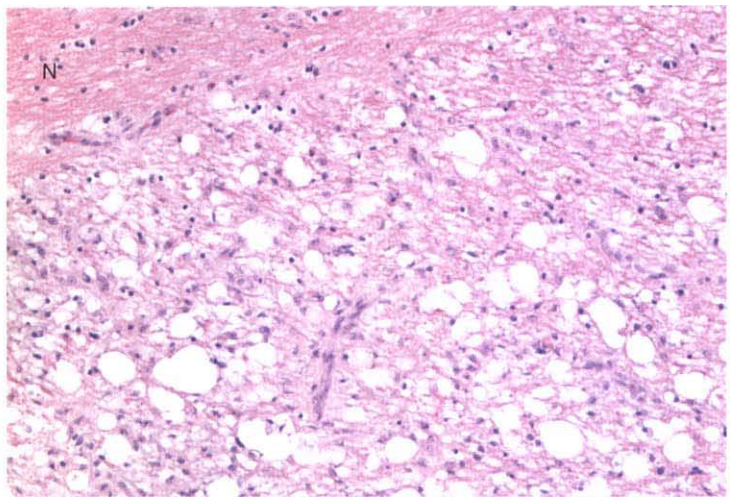
**11-19** Reactive astrocytes ('gemistocytes')
Cerebrum. Hypertrophic astrocytes with swollen, eosinophilic, homogeneous cytoplasm and large eccentric nuclei. These astrocytes may form slender, long processes giving the neuropil a fibrillary appearance. Cat. HE.



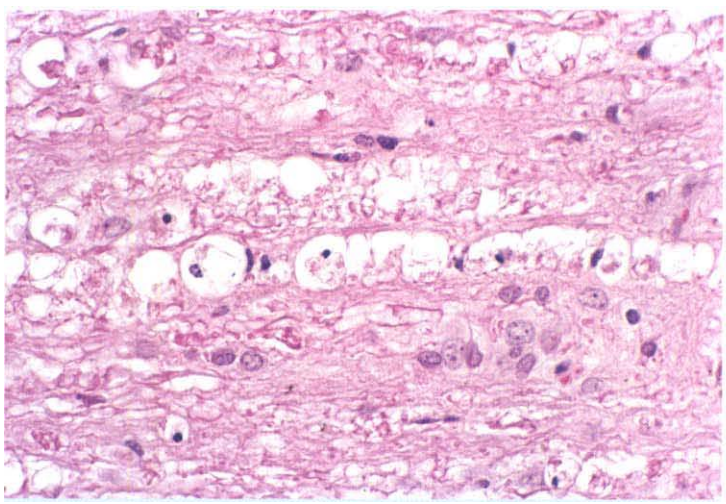

**11-20** Gitter cells (phagocytic macrophages)
Cerebellar peduncle. Area of malacia showing phagocytosis of myelin and necrotic tissue by macrophages derived from monocytes and microglial cells. These cells (referred to as Gitter cells) have large rounded cell bodies, granular and often vacuolar cytoplasm and eccentric nuclei. Some remnants of neuropil (N). Focal symmetrical encephalomalacia. Sheep. HE.



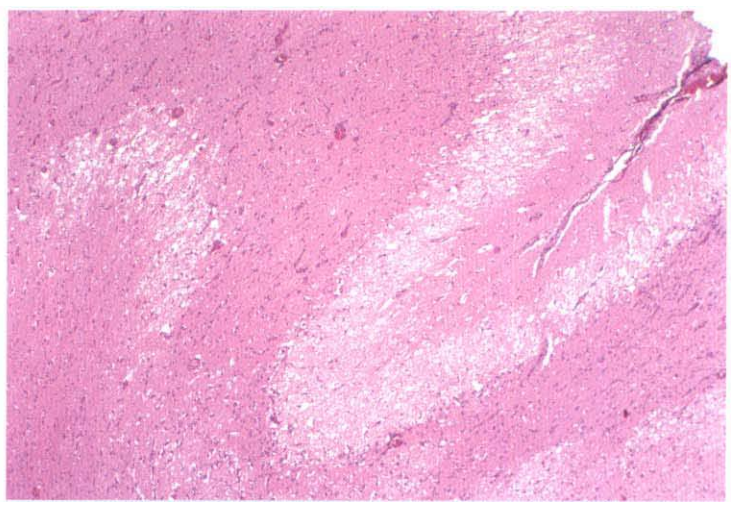
**11-21** Demyelination
Cross section through spinal cord. Bilateral myelin pallor in dorsal, dorsolateral and lateral funiculi histologically associated with demyelination, axonal swelling and reactive astrocytosis. Lesions consistent with leukoencephalomyelopathy. Leonberger dog, 2 years. Kluver Barrera stain for myelin.



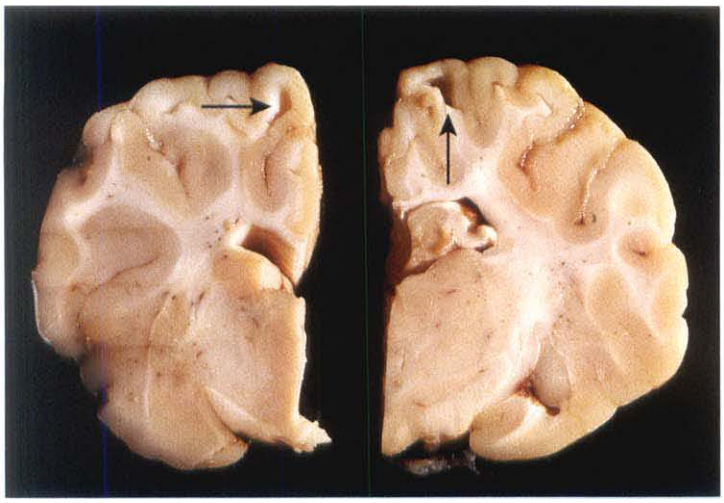

**11-22** Primary demyelination
Cerebellar white matter. Focal area of myelin loss characterized by initial preservation of axons and swelling of myelin sheaths. There is concurrent astrocyte hyperplasia and microglial proliferation. Normal white matter left top (N). Distemper. Dog. HE.



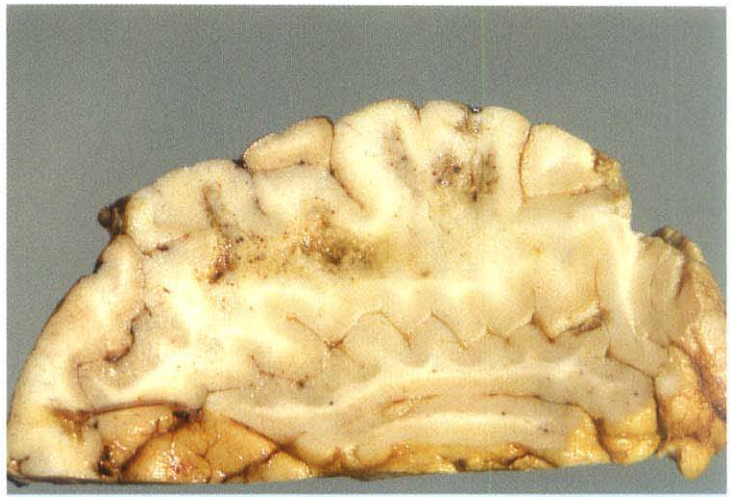
**11-23** Secondary demyelination (Wallerian degeneration)
Spinal cord white matter, parasagittal section. Longitudinal chain of digestion chambers containing axon and myelin debris and small phagocytes with indistinct cell bodies, vacuolated cytoplasm and pyknotic nuclei. Disintegration and phagocytosis of myelinated fibers secondary to neuronal (axonal or perikaryal) damage. Sheep. HE.



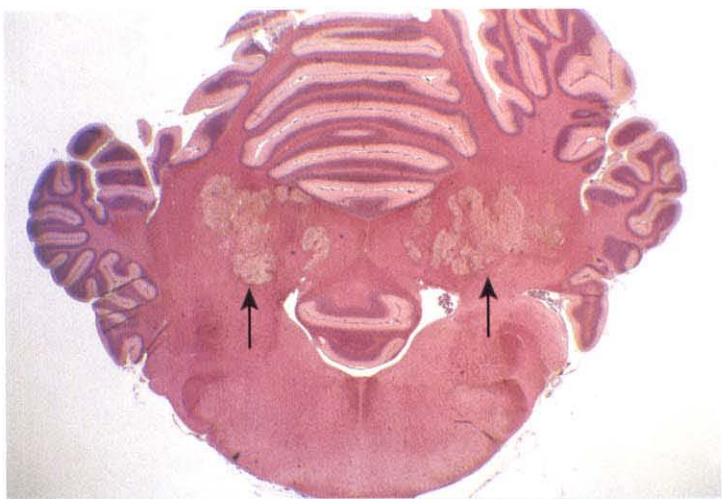
**11-24** Acute polioencephalomalacia
Cerebral cortex. Multiple microcavities, resulting from swelling of astrocytic processes (intracellular edema), produce a spongy appearance of the superficial laminae in the cortical parenchyma. Note the laminar distribution. Extensive neuronal necrosis, hyperplastic capillaries and eosinophilic infiltration (not visible at this magnification) can be present, even in the structurally intact middle laminae. Salt poisoning. Pig. HE.



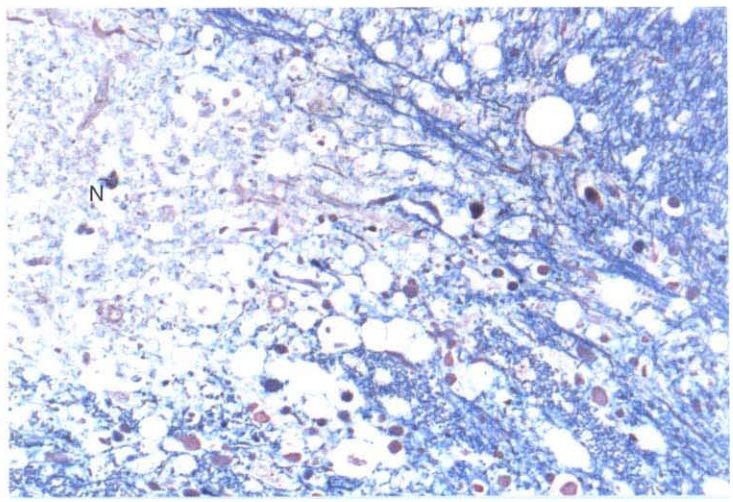
**11-25** Subacute polioencephalomalacia
Brain, transverse section through diencephalon. Liquefactive necrosis (malacia) of cerebral cortex, partly removed by phagocytosis (arrows). This process starts in the deep cortical laminae causing cleavage of cortical remnants from the subjacent intact white matter. Thiamine deficiency. Goat.



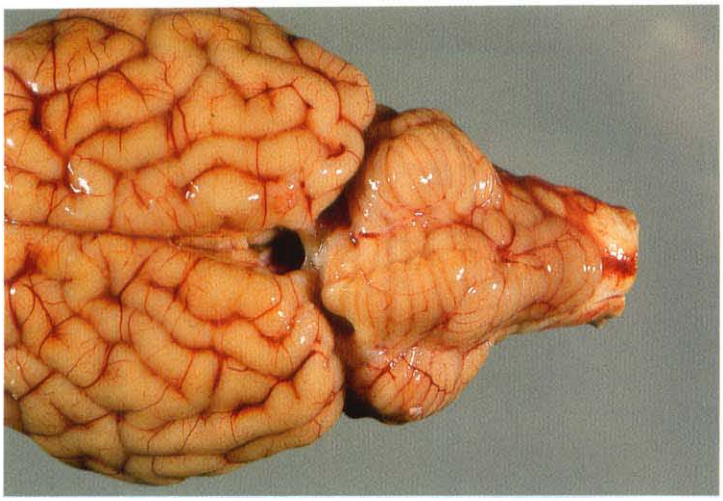
**11-26** Chronic leukoencephalomalacia
Transverse section of cerebrum. Irregular often confluent areas of malacia, cavitation and hemorrhage affecting the white matter. Leukoencephalomalacia caused by the toxin fumonisin B produced by the fungus *Fusarium moniliforme*. Horse.



**11-27** Symmetrical encephalomalacia
Brain, transverse section, through cerebellum. Symmetrical pale areas (arrows) in cerebellar medulla due to edema and necrosis of parenchyma. Lesions are the result of the action of *Clostridium perfringens* type D toxins on the vascular endothelium. Focal symmetrical encephalomalacia. Lamb. HE.

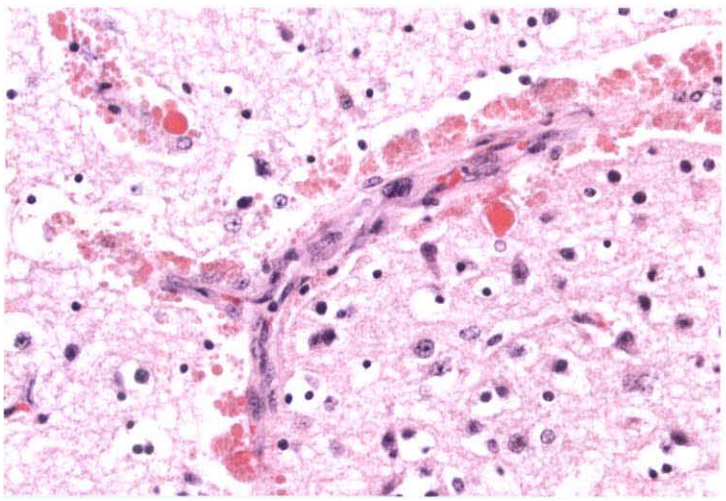



**11-28** Malacia
Cerebellar peduncle. Area of malacia (N) evidenced by necrosis of neuropil and loss of myelin. Note distended myelin sheaths and swollen axons in adjacent white matter. Focal symmetrical encephalomalacia. Sheep. Luxol fast blue-Holmes stain for myelin and axons, respectively.

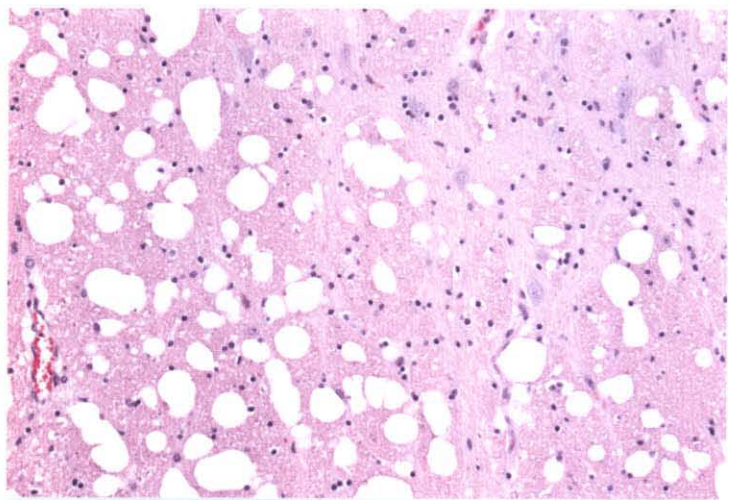


**11-29** Cerebellar coning
Caudal brain, dorsal view. Tongue-shaped distortion of posterior cerebellar vermis due to herniation through foramen magnum. Caused by ventricular distention by exudate (pyocephalus) following canulation of third ventricle. Also seen with edematous brain swelling, intracranial tumors and other space occupying lesions. Goat.

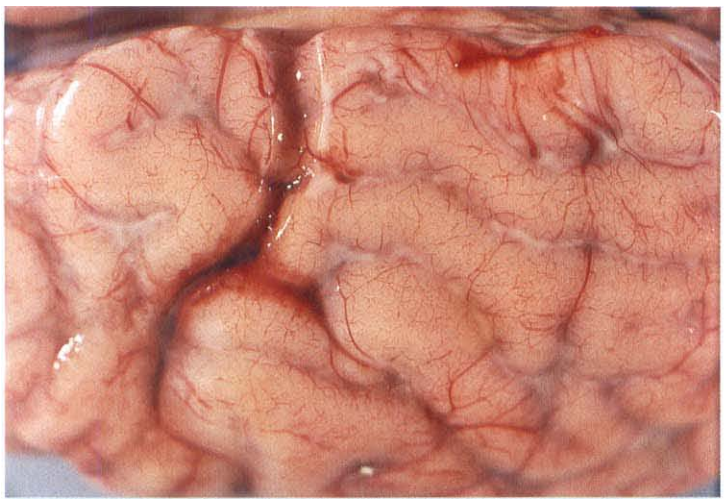
**11-30** Cerebral edema
Cerebral white matter. Perivascular accumulation of protein rich fluid and minor hemorrhage resulting from increased vascular permeability. Enterotoxemia. Sheep. HE.



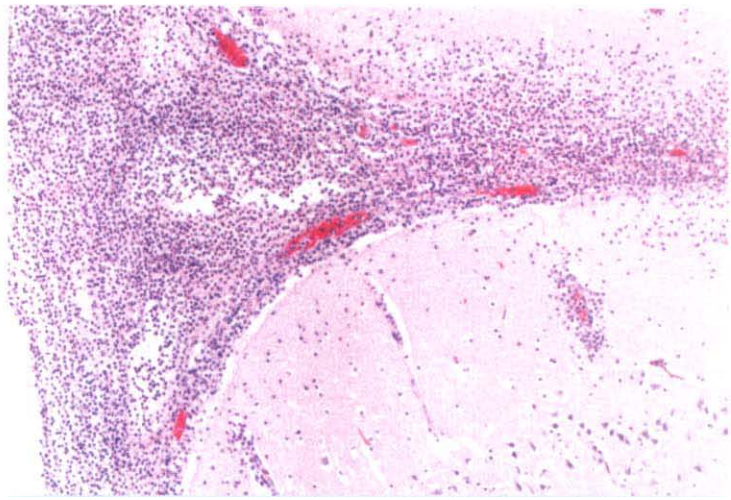
**11-31** Cerebral edema
Cerebrum. Droplets of hyaline, eosinophilic material accumulate around small blood vessels in the neuropil at the glia limitans. The initial lesion manifests as perivascular edema due to vascular injury. Edema disease. Pig. HE.



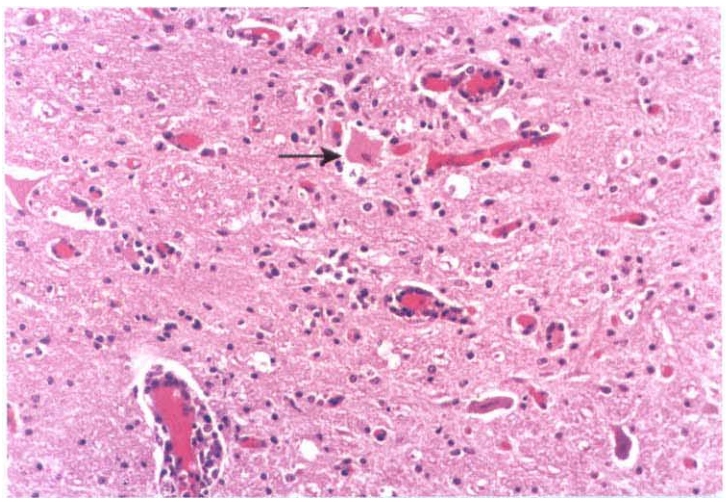
**11-32** Spongy vacuolation.
Medulla oblongata. The white matter contains numerous empty, more or less irregular vacuoles representing intramyelinic edema. Note absence of inflammation. Hepatic encephalopathy. Dog. HE.



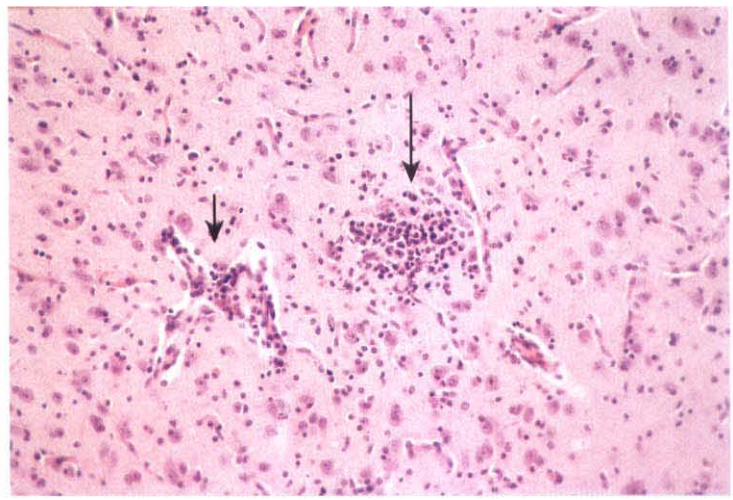
**11-33** Fibrinopurulent leptomeningitis
Cerebral surface. Accumulation of grayish-yellow exudate in subarachnoid space overlying the sulci, obscuring blood vessels. In young animals, especially calves, piglets and foals, it is usually caused by a hematogenous bacterial infection. Calf.



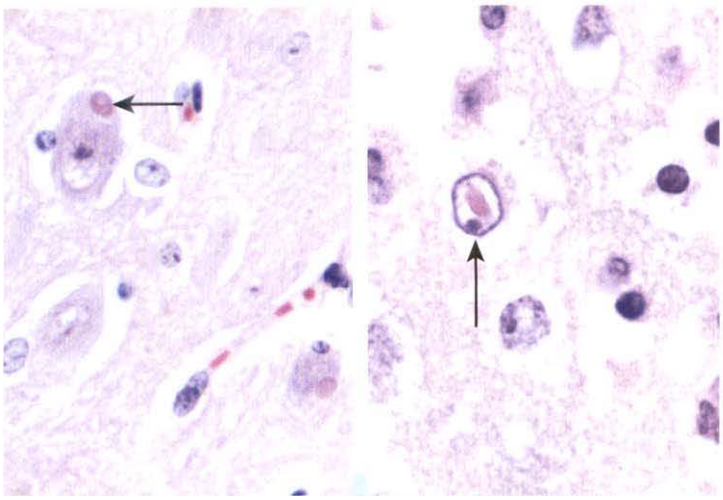
**11-34** Fibrinopurulent leptomeningitis
Cerebral cortex with sulcus. Accumulation of inflammatory cells, predominantly neutrophils, and serofibrinous exudate in subarachnoid space. Extension along Virchow-Robin's spaces (cuffing of blood vessels). Slight invasion of superficial cerebral parenchyma. Calf. HE.



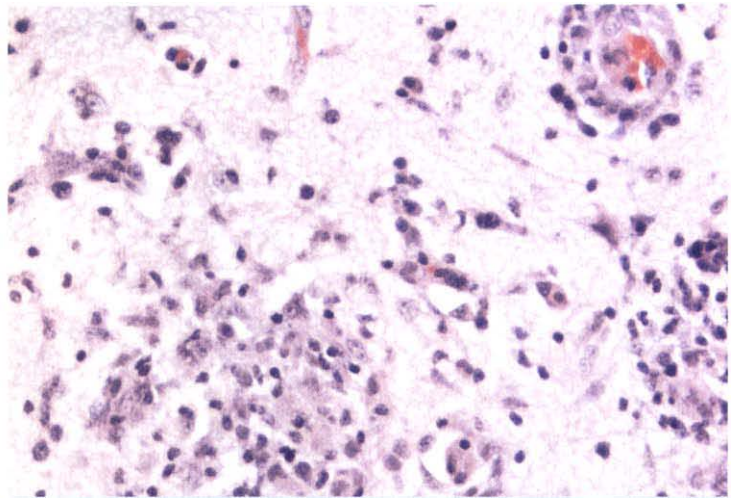
**11-35** Viral polioencephalomyelitis
Cerebrum. Lymphocytic inflammation of the gray matter, perivascular cuffing, neuronal necrosis (arrow) and neuronophagia. These lesions are characteristic features of viral infections of the central nervous system. Rabies. Cow. HE.



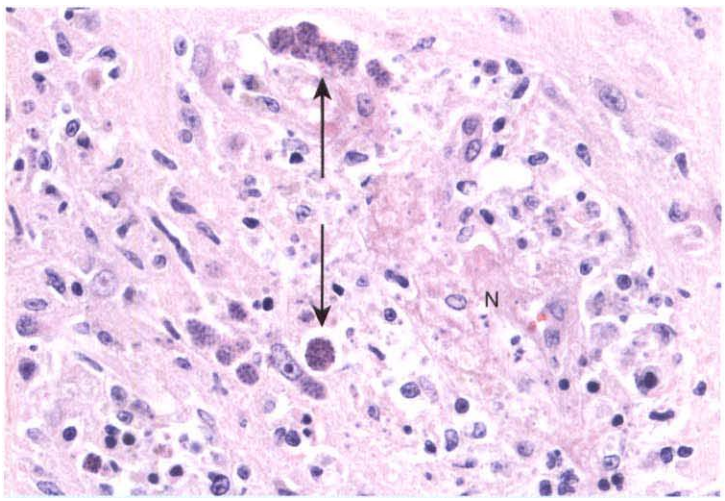
**11-36** Microglial nodule
Brain. Focal aggregation of proliferating microglial cells in the neuropil referred to as a microglial nodule (long arrow). Note perivascular cuffing (short arrow). Aujeszky's disease. Piglet. HE.



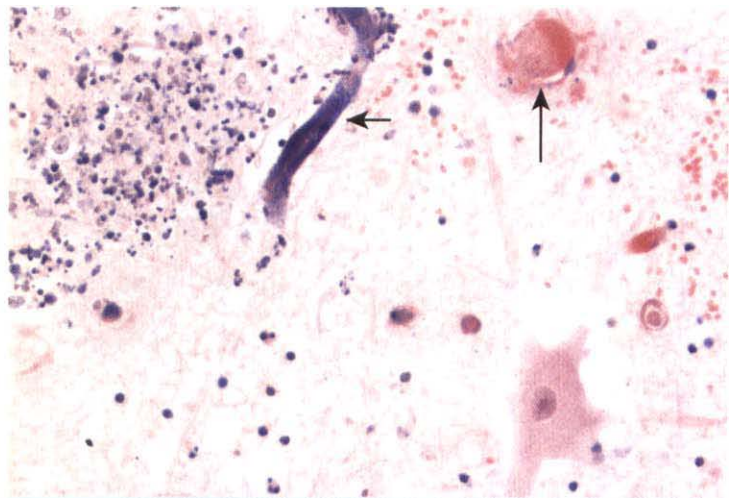
**11-37** Viral inclusion bodies
Left: neuron containing an eosinophilic intracytoplasmic inclusion body in which an inner body is present (Negri body; arrow). Rabies. Cow. HE.
Right: Astrocyte showing an eosinophilic intranuclear inclusion body resulting in margination of chromatin (arrow). Distemper. Dog. HE.



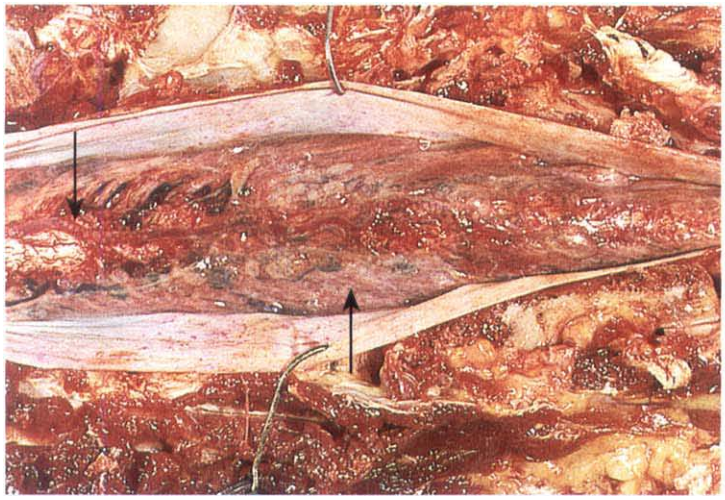
**11-38** Granulomatous inflammation
Cerebrum. Infiltration of macrophages and lesser numbers of lymphocytes and plasma cells consistent with granulomatous inflammation around blood vessels and in the neuropil. Encephalitozoonosis. Dog. HE.



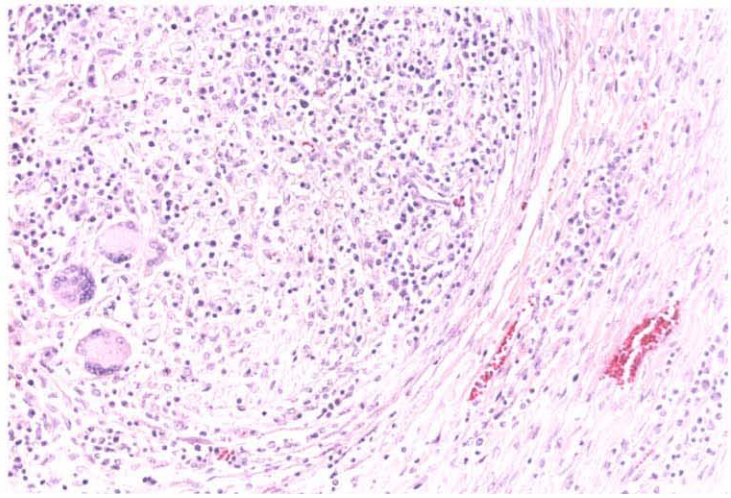

**11-39** Necrotizing encephalitis
Cerebrum. Necrosis of the neuropil (N) and infliltration of mononuclear cells within and adjacent to the necrotic focus. Note protozoal cysts (arrows). Toxoplasmosis. Cat. HE.



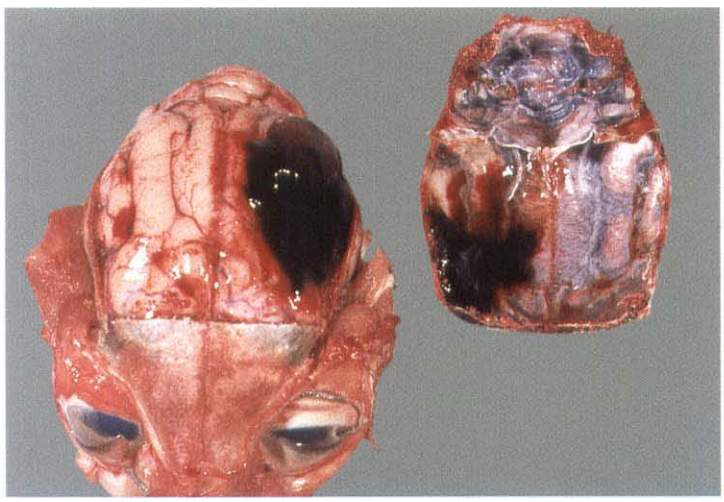
**11-40** Vasculitis, thrombosis and infarction
Cerebrum. Vasculitis with fibrin thrombosis (long arrow), a vessel containing bacterial colonies (short arrow), infiltration by neutrophils (left top) and pale-staining neuropil due to infarction. Thrombotic meningoencephalitis caused by *Haemophilus somnus*. Cow. HE.



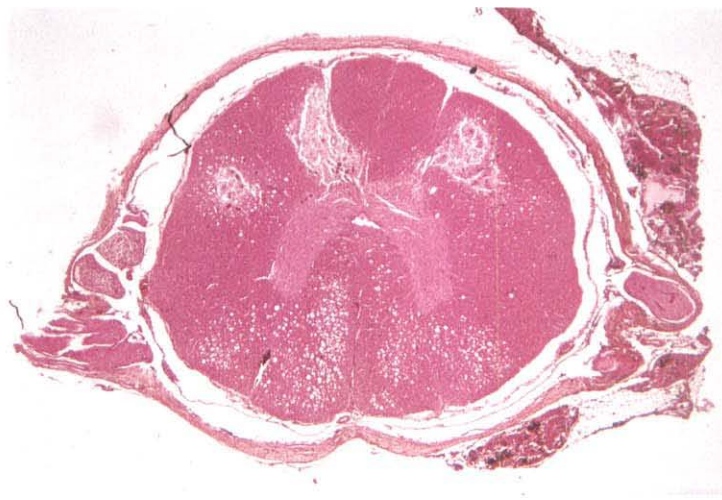
**11-41** Inflammation of extradural spinal roots
Caudal spinal cord with dura mater reflected. Note red discoloration and multiple grayish nodules due to granulomatous inflammation of the extradural nerve roots (arrows). Neuritis of the cauda equina. Horse.



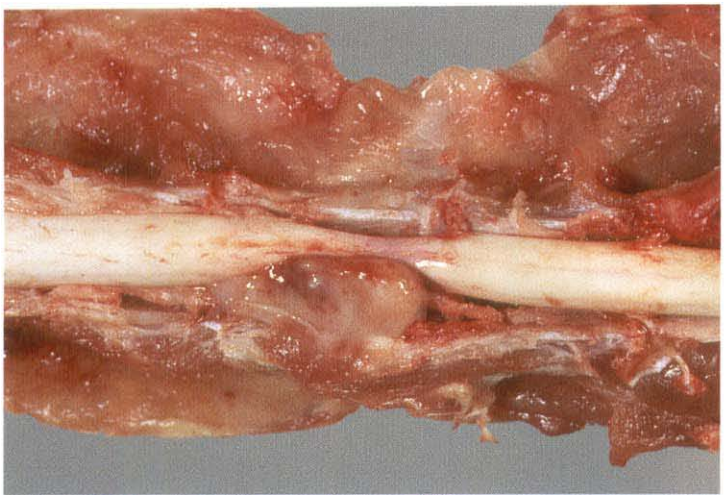
**11-42** Inflammation of extradural spinal roots
Sacrocaudal nerve bundles, transverse section. Infiltration of mononuclear cells into epi-, peri- and endoneurium with resultant demyelinization and degeneration of axons. Occasional giant cell formation and marked epineural fibrosis are seen. Neuritis of the cauda equina. Horse. HE.



**11-43** Extradural hematoma
Dense blood clot overlying left hemisphere between dura mater and skull, causing cerebral compression. Usually due to skull fracture with laceration of a blood vessel. Cat.

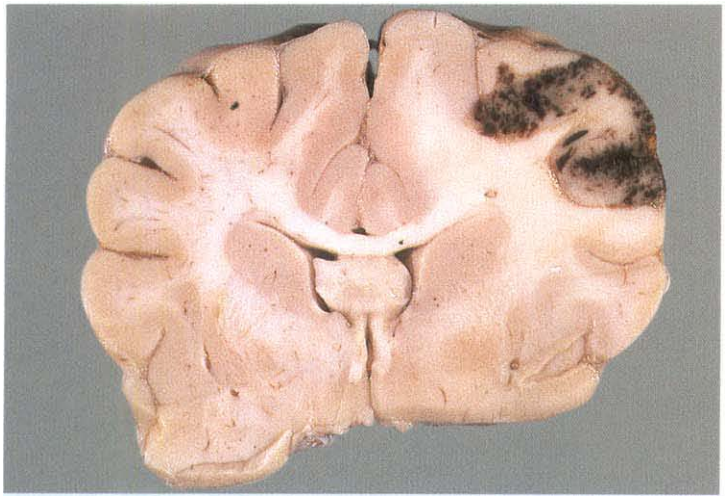


**11-44** Spinal cord injury due to intervertebral disc extrusion
Lower thoracic spinal cord, transverse section. Areas of malacia mainly involving dorsal and lateral funiculi. Note diffuse Wallerian degeneration in ventral funiculi. 12 day survival, Cocker spaniel. HE.

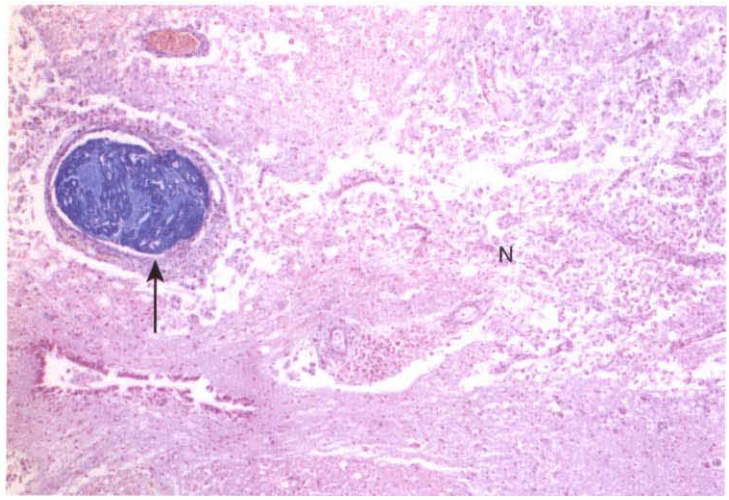


**11–45** Spinal cord compression
Lumbar spinal cord after removal of vertebral laminae, dorsal view. Severe compression of spinal cord by extradural malignant lymphoma. Cat.

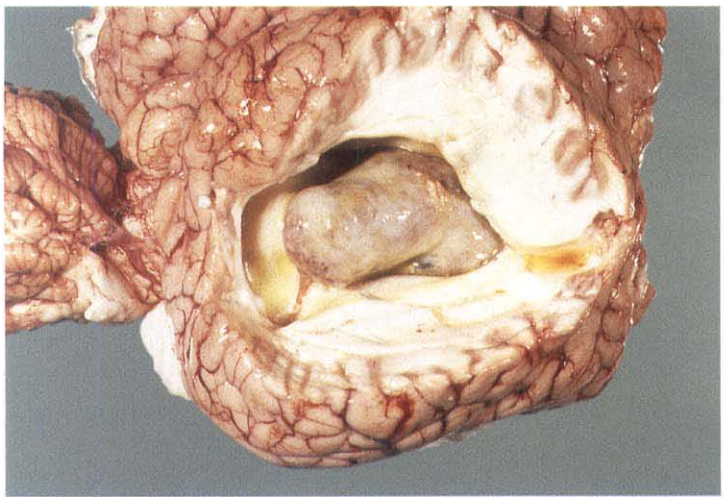
**11–46** Avulsion of the brachial plexus
Spinal cord, cervical intumescence, ventral view. Hemorrhagic remnants of left C7, C8 and T1 root sleeves contrasting with normal roots on the opposite side. Complete intradural avulsion of dorsal and ventral roots, due to traction during excessive abduction of left fore leg. 4 day survival. Dog.



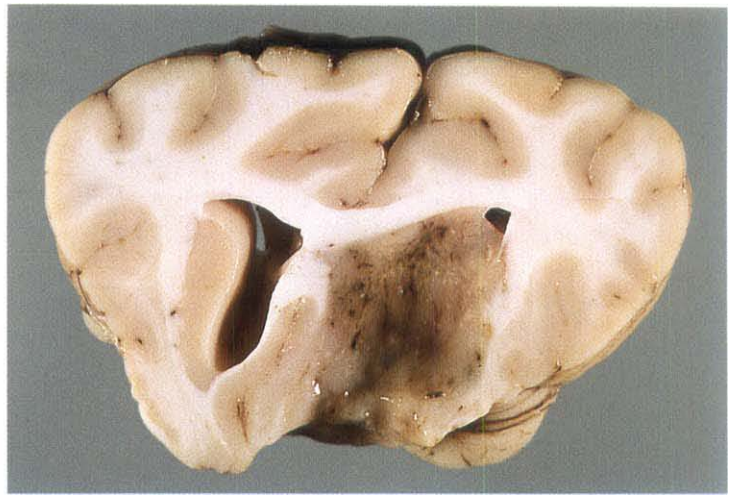
**11–47** Acute cerebral infarct
Frontal lobes, transverse section. Well demarcated hemorrhagic infarct in right cerebral hemisphere, largely confined to the cortex. Edematous swelling of adjacent white matter. Dog.




**11–48** Spinal cord infarction
Spinal cord segment, transverse section. Well-defined necrotic area (N) containing numerous macrophages and involving both white and gray matter. An artery is occluded by an alcianophilic cartilagenous embolus (arrow), originating from intervertebral disc material.
Fibrinocartilagenous embolic myelopathy. Dog. Alcian blue stain for glycosaminoglycans.

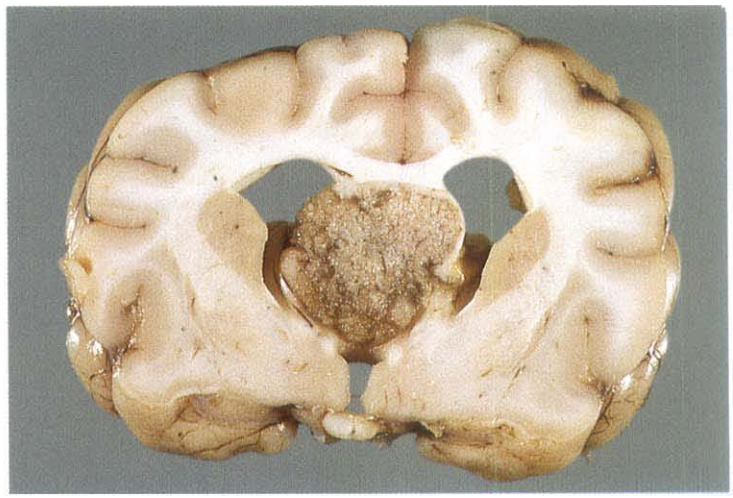


**11-49** Cholesteatoma
Tumor-like nodule in choroid plexus of right lateral ventricle. Granulomatous inflammation induced by deposition of cholesterol. Occurs frequently in old horses, may attain a large size, and occasionally causes obstructive hydrocephalus. Horse.



**11-50** Oligodendroglioma
Brain, transverse section through frontal lobes, frontal view. Soft hemorrhagic tumor mass in the region of the left caudate nucleus (typical location). Almost complete obliteration of the lateral ventricle, with distortion of adjacent structures. Relatively common, especially in brachycephalic dogs. Boxer dog.

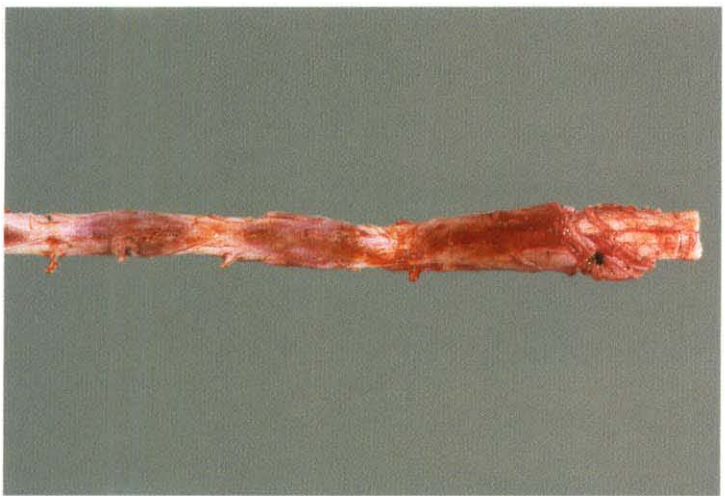
**11-51** Meningioma
Caudal brain stem and cerebellum, sagittal section. Well-defined tumor mass with fibrillar pattern on cut surface. Severe compression of medulla oblongata. Shetland sheepdog.



**11-52** Plexus papilloma
Brain, transverse section through optic chiasm. Well-circumscribed expansive growth with granular papillary appearance, distending the third ventricle with consequent obstructive hydrocephalus. Usually benign tumor of choroid plexus epithelium, occurring in any of the cerebral ventricles or at the cerebellopontine angle. Dog.

**11-53** Neurofibrosarcoma
Spinal cord, cervical intumescence, dorsal view. Elongated tumor mass involving right C6 spinal roots, ganglion and spinal nerve distally to the brachial plexus. The tumor extended intradurally and compressed the spinal cord. There was associated neurogenic atrophy of the scapular muscles. Labrador retriever dog.

**11-54** Intradural-extramedullary spinal cord tumour
L1 spinal cord segment, transverse section. Tumor mass occupying most of the intradural space and displacing the spinal cord. Mixed tumor, composed of neuroepithelial elements and squamous epithelial cysts, probably of embryonal origin. Thoracolumbar spinal cord tumor of young dogs. Bull terrier dog, 2 years. HE.



**11-55** Dura mater osseous metaplasia
Spinal cord, formalin fixated. Several very firm, red-brownish plaques in the dura mater seen as an incidental finding in old dogs. Dog.

**11-56** Osseous metaplasia
Cross section of spinal cord. The dura mater is distended by plaques of lamellar bone containing hematopoietic elements (arrows). The spinal cord is not compressed or otherwise affected. Dog. HE.

Chapter 12

# The locomotory system

# THE LOCOMOTOR SYSTEM

The locomotor system includes bones, joints, tendons and muscles.

The most common lesions are:

- congenital anomalies;
- metabolic disorders;
- inflammation; and
- neoplasia.

## Bones

In bone some specific points that influence the pathogenesis of lesions need to be considered.

- It is important to realize the basic difference between young growing and adult full-grown animals (Diag. 12A).
- In growing animals bone apposition in long bones is after *chondral growth* in the physeal growth plate and in the bone-facing layer of the articular cartilage.
- Disorders associated with the growth of cartilage and its transformation to bone develop at both sides, near the growth plate in the metaphysis and near the joint cartilage in the epiphysis.
- The subchondral tissue is highly vascularized, with hairpin loop microanatomy of blood vessels, which favors bacterial embolism and *osteomyelitis*.
- Longitudinal *growth of bones* is favored by various factors, such as insulin-like growth factors I and II, by transforming growth factor beta (TGFβ) in the cartilage, by apoptosis of chondrocytes, and by mineralization of the surrounding cartilage matrix. Multinucleated chondro- and osteoclasts remove the calcified cartilage, followed by ingrowth of highly vascularized mesenchymal tissue with osteoblasts responsible for bone apposition. Growth is stimulated, among other factors, by food, insulin, thyroxine, androgens and TGFβ. Inhibition is caused by malnutrition, estrogens and glucocorticosteroids.
- In *adult* domestic animals the physis is closed and the spectrum of pathological mechanisms is less variable than in juveniles.
- Primary neoplasms develop more frequently in older animals; in addition to *primary tumors*, metastatic tumors may occur in the bones.

In bone tissue the mesenchymal stroma (in particular the *osteoblast*) is the leading structure in anabolic as well as in catabolic processes.

### Anabolic processes

Anabolic processes result in bone formation by osteoblasts. Regulating factors, such as growth hormone, calcitonin, parathormone, vitamin D, steroid hormones and IGF-I, in low concentrations, activate anabolism. When higher concentrations occur, catabolism is stimulated.

### Catabolic processes, RANK/RANKL system

Catabolic processes are evidenced by bone removal through *osteoclasts*. The latter are stimulated by cytokines that originate mostly from the osteoblasts (Diag. 12B).

An important component in this process of bone resorption is a receptor on the osteoclast, i.e. the receptor activator of nuclear factor kappa B (RANK).

This receptor can be stimulated by RANK-ligand (RANKL) from osteoblasts, thus resulting in bone resorption and bone loss, or can be blocked by osteoprotegerin (OPG) from the same cellular origin. RANKL and OPG are regulated by various hormones (glucocorticoids, vitamin D, estrogen) and cytokines (TNFα, interleukins). RANKL and OPG play a crucial role in extraskeletal calcium metabolism (calcification, development of a lactating mammary gland during pregnancy) by their influence on bone, and thus, in the pathogenesis of metabolic bone diseases. Osteoclasts are also stimulated by other pro-inflammatory cytokines released by osteoblasts and other mesenchymal cells, such as inflammatory cells.

## Joints

In joint pathology three major processes are seen:

- cartilage degeneration related to *dyschondroplasia* in growing animals;
- cartilage degeneration related to mechanical (relative) *overloading* of young and adult animals; and
- inflammation.

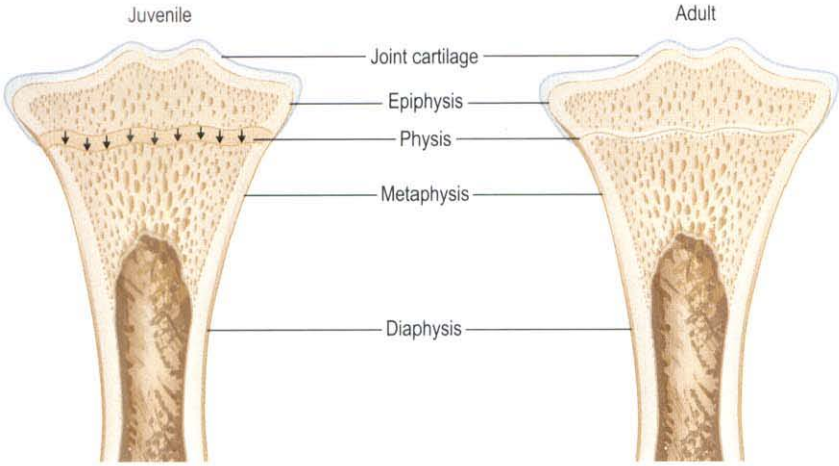
Clinical symptoms during inflammation are merely related to inflammatory reactivity rather than to the morphological changes.

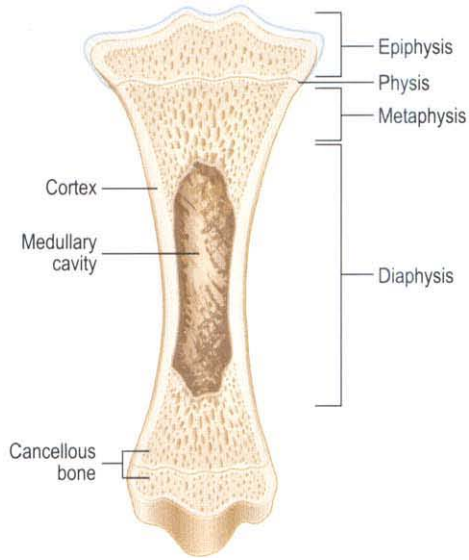
## Muscles

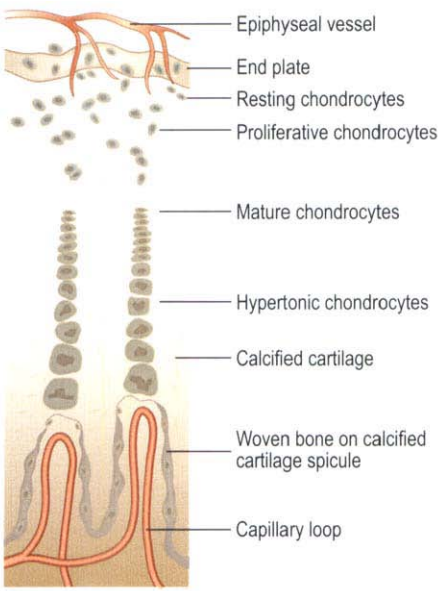
*Cellular lesions* with a nutritional/toxic, metabolic or hereditary origin, dominate muscular pathology.

- Most nutritional/toxic disorders affect oxygen-related metabolic processes, leading to lesions of slow-reacting mitochondrion-rich, red colored aerobic muscle fibers.
- Metabolic and hereditary lesions more often affect the rapid reacting pale colored anaerobic muscle fibers.

In addition, *inflammatory lesions* frequently occur in muscles. Along with different etiologies zoonotic agents have to be considered.



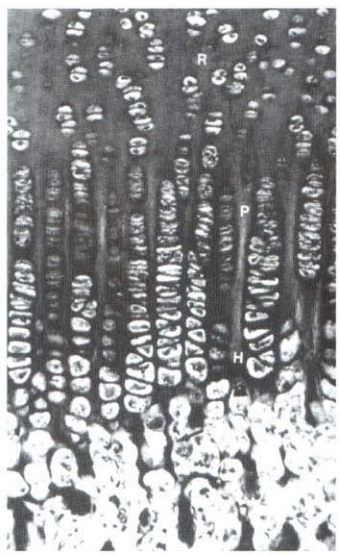
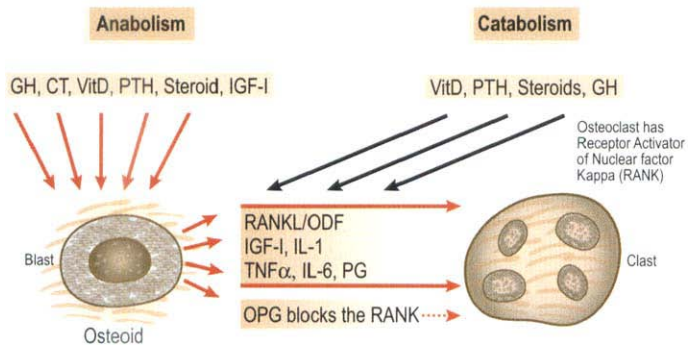




**Diagram 12A. Growth regulation**
Locally in cartilage and systemically from liver, resp. IgF-II and IgF-I stimulate mitoses in growth plate (TGFβ).
After apoptosis of chondrocytes, calcification of matrix and removal by chondro-osteoclasts, bone formation occurs.
*Stimulation of growth by food, insulin, thyroxine, androgens, TGFβ; inhibition by malnutrition, estrogens and glucocorticoids.*

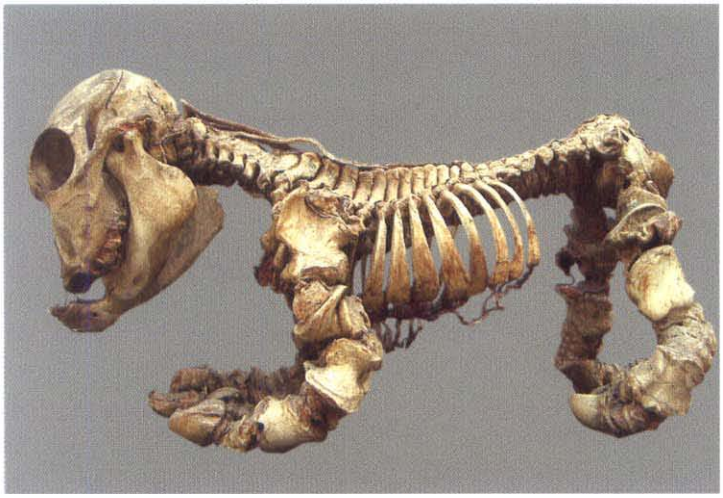



Mineralization of osteoid:
Ca, P, VitD, CT

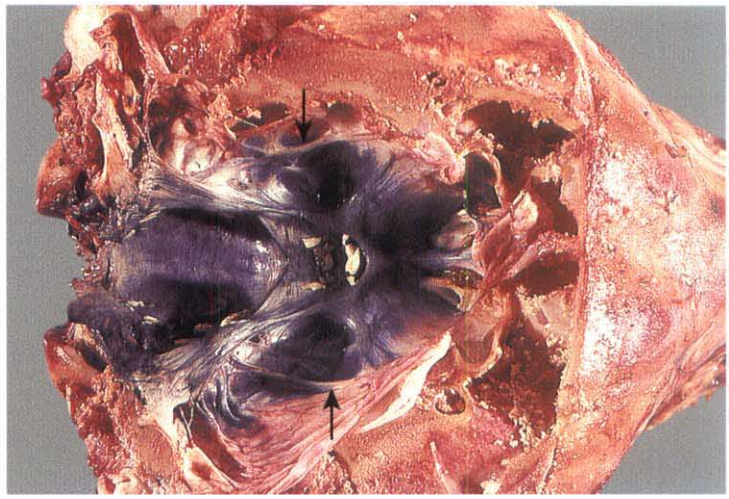
Osteoclasts are inhibited by unmineralized osteoid and CT, and via osteoblasts: TGFβ, OPG

**Diagram 12B. Growth regulation**

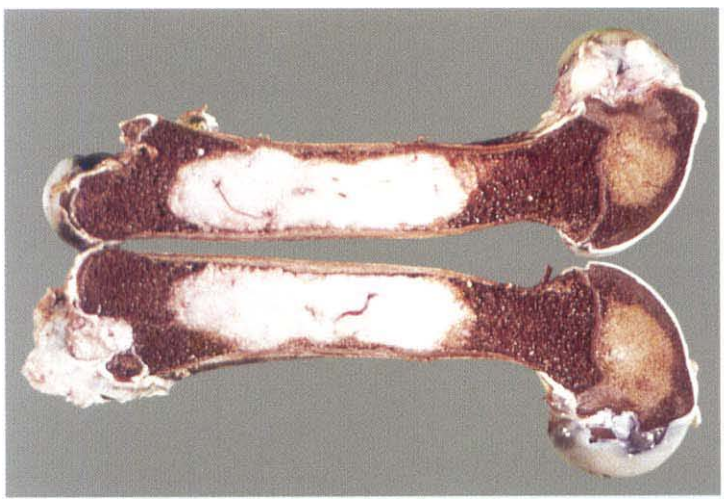
| | | |
|---|---|---|
| CT | = | calcitonin |
| GH | = | growth hormone |
| ODF | = | osteoclast differentiation factor |
| | = | RANK-Ligand (RANKL) |
| OPG | = | osteoprotegerin |
| PG | = | prostaglandins |
| PTH | = | parathormone |
| VitD | = | vitamin $D_3$ |



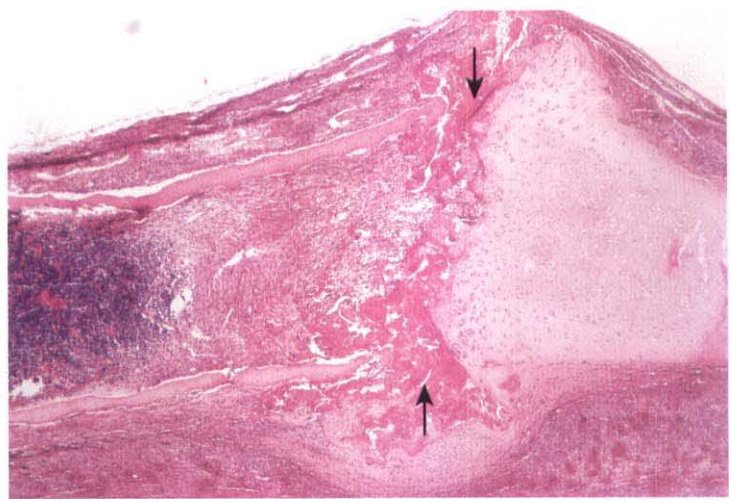
**12-1** Fetal chondrodysplasia
Fetal skeleton. Retardation of chondral growth, resulting in shortening of all enchondrally formed bones, including the cranial base ('bulldog calf'). Neonatal calf.



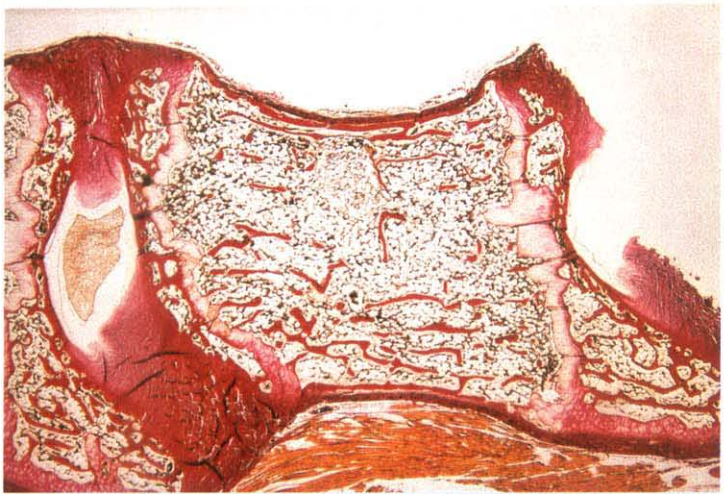
**12-2** Periosteal melanosis
Black-stained periosteum of base of skull (arrows) due to melanin formed by ectopic melanocytes. Cow.



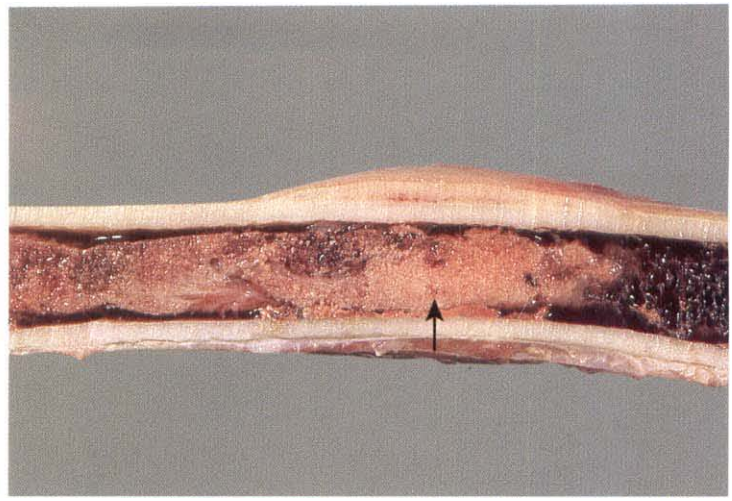
**12-3** Congenital porphyria (*Porphyria congenita*)
Femur, sagittal section. Diffuse brownish discoloration of the mineralized cancellous and cortical bone. Cartilage and bone marrow are normal-colored. Teeth (not shown) have pink colour. Calf.



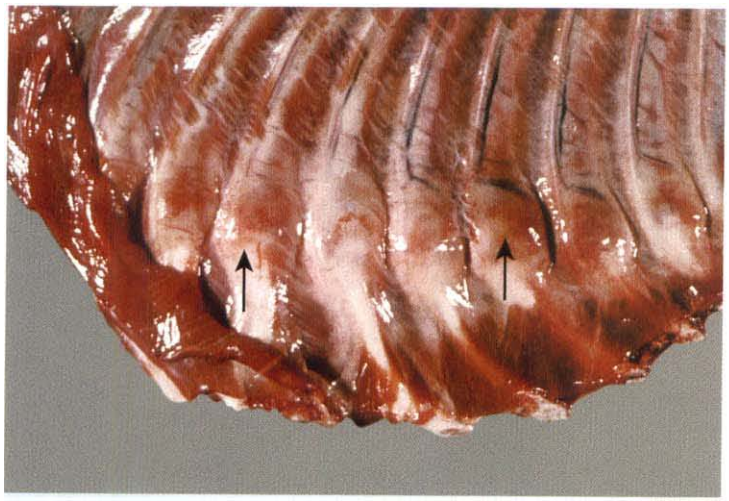
**12-4** Hypoplastic osteoporosis due to scurvy
Rib, costochondral (from left to right) junction. Irregularity of the cartilage surface adjacent to secondary fracture (arrows) of compacta and spongiosa with deposition of fibrinous material in primary spongiosa. Proliferation of loosely arranged mesenchymal cells in metaphysis, proliferation of poorly differentiated periosteal fibroblasts and finally normal bone marrow (left). Hemorrhages in surrounding musculature. Defective osteogenesis caused by hypovitaminosis C is often found in guinea pigs receiving rabbit food. Guinea pig. Demineralized section. HE.



**12-5** Hypoplastic osteoporosis
Vertebral body, sagittal section. Severe deformation and collapse, growth plates producing insufficient bone tissue, and severe reduction of cancellous bone, all caused by diminished activity of osteoblasts. Cat, 5 months. Demineralized section. Van Gieson.

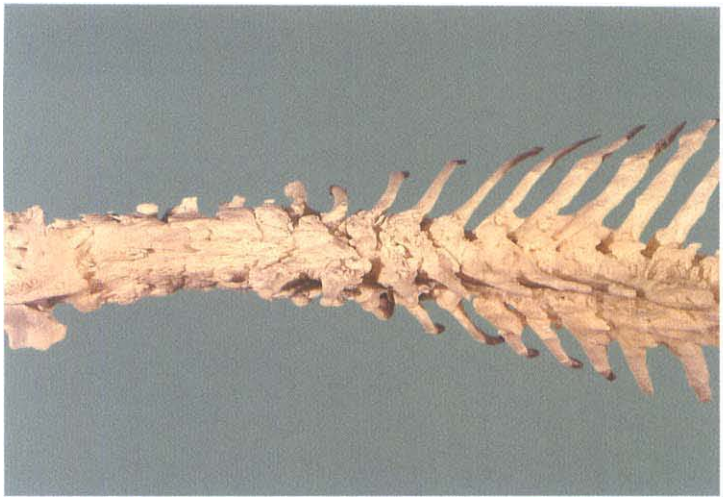


**12-6** Myelosclerosis
Femur, mid shaft, sagittal section. Large irregular mass of dense cancellous bone (arrow) in the primary marrow cavity, caused by hyperplasia and hyperfunction of osteoblasts. Hyperplastic bone marrow is present. Chronic anemia. Adult dog.

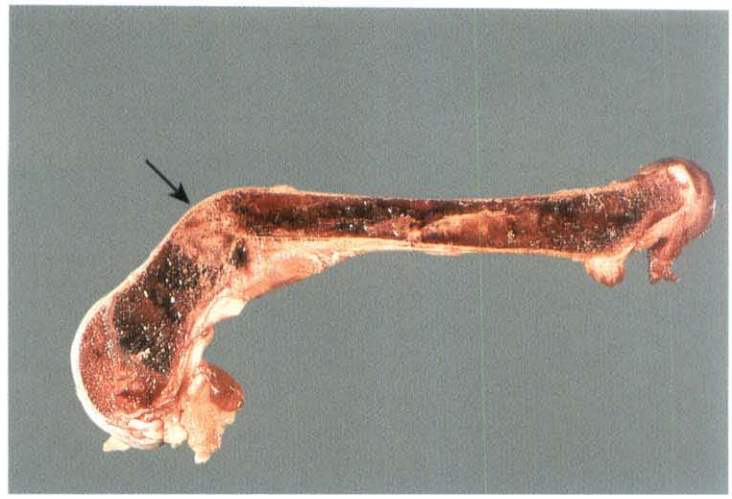


**12-7** Rickets
Ribs. Note rosary formation (arrows) on costochondral junction due to widening of the metaphyseal area. Belgian Tervueren sheepdog, 6 months.

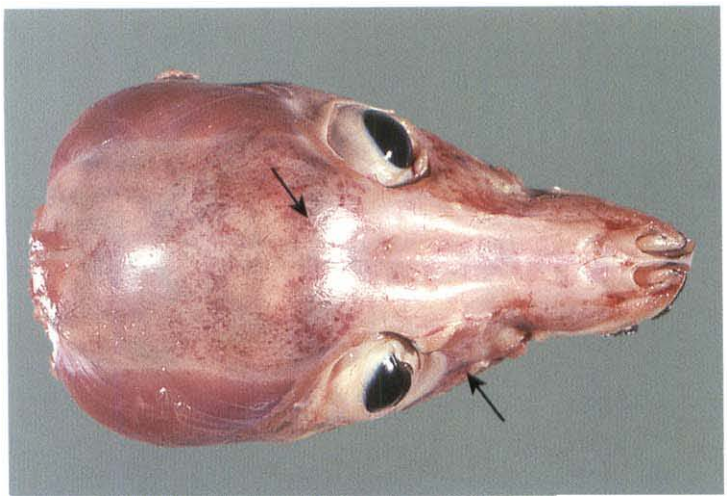
**12-8** Rickets
Rib, costochondral junction on sagittal section. Deep, irregular metaphyseal growth plate (right), with local absence of provisional mineralization of cartilagenous matrix and newly formed osteoid. Some black-stained mineralized bone trabeculae (left) with broad seams of osteoid (red) and trabeculae consisting of only osteoid (rachitic metaphysis/rachitic rosary). Goat, 1 year. Non-demineralized section. Von Kossa's method for calcified tissue.



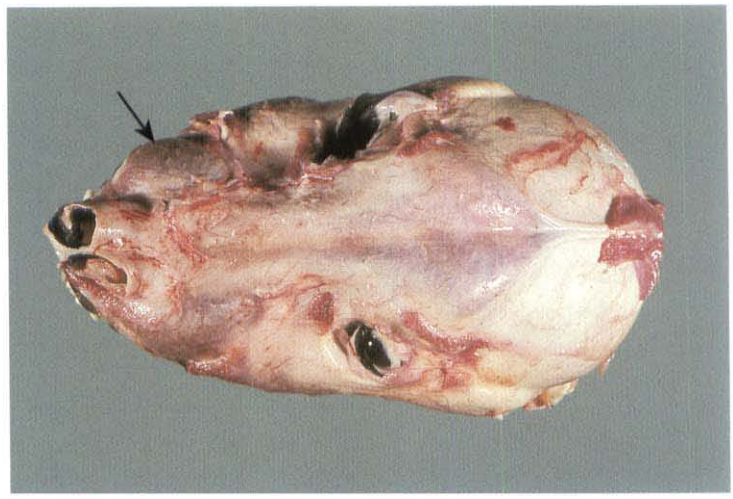
**12-9** Resorptive osteoporosis due to toxicity with reactive periosteal bone formation
Spine, macerated specimen. Multiple confluent exostoses with severe ankylosis on the dorsolateral aspects of the cervical and thoracic vertebrae. These exostoses are a response to resorptive osteoporosis in the underlying bone, associated with longstanding uniform liver diet that resulted in chronic hypervitaminosis A. Cat.



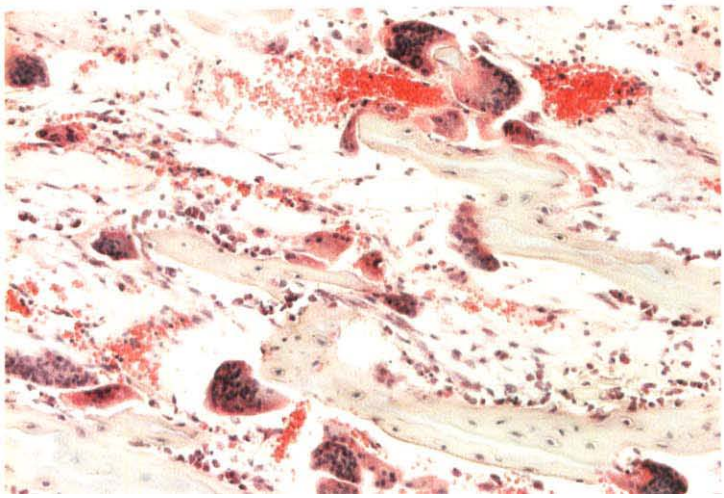
**12-10** Hypo-ostotic fibrous osteodystrophy
Femur, sagittal section. Very thin cortices, wide primary marrow cavity, diminished cancellous bone, greenstick fracture in the distal diaphysis (arrow). Nutritional secondary hyperparathyroidism. Collie dog, 5 months.



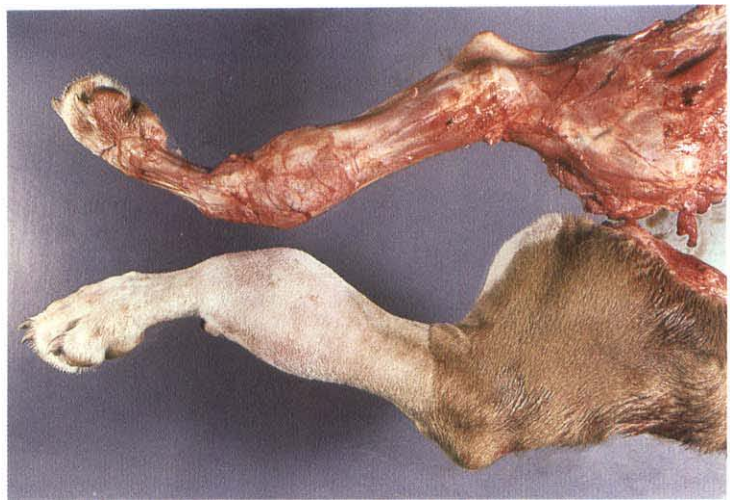
**12-11** Fibrous osteodystrophy (*osteodystrophia fibrosa*)
Soft reddish bones of the skull and maxilla (arrows). The subperiosteal bone is resorbed, and replaced by vascularized fibrous tissue. Secondary hyperparathyroidism due to renal failure. Adult dog.



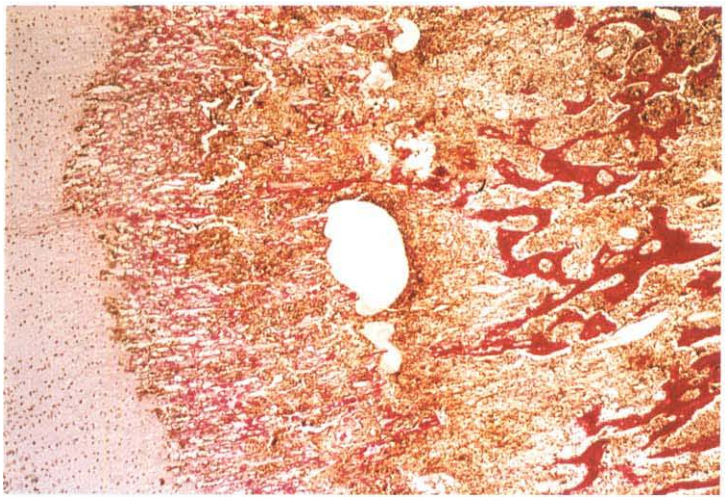
**12-12** Hyperostotic fibrous osteodystrophy (hypertrophic osteodystrophy) in juveniles
Greatly thickened jaws (arrow) due to the influence of dentition on the osteodystrophic process. Secondary hyperparathyroidism due to familial nephropathy. Dog, 6 months.



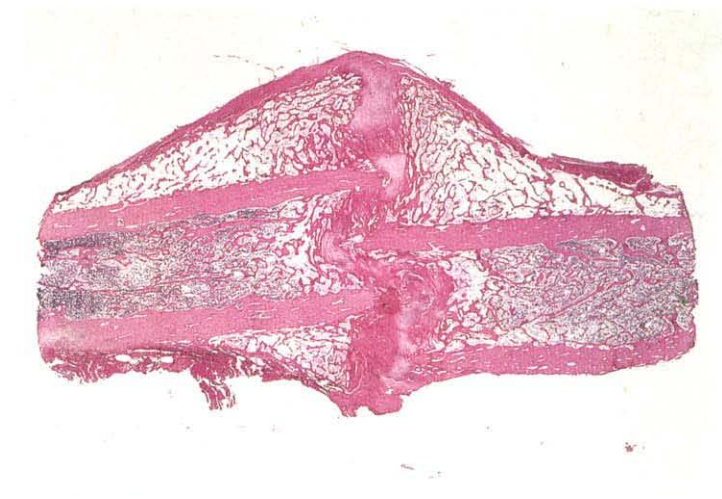
**12-13** Fibrous osteodystrophy (*osteodystrophia fibrosa*)
Numerous multinucleated osteoclasts resorbing bone and thus forming Howship's lacunae. The bone resorption is associated with exchange of bone for fibrous tissue. Nutritional secondary hyperparathyroidism. Great Dane dog, 5 months. Demineralized section. HE.



**12-14** Metaphyseal osteopathy (hypertrophic osteopathy or osteodystrophy)
Thickening of distal metaphysis of radius and ulna due to a catabolic process in its primary spongiosa associated with periosteal growth of connective tissue, cartilage and bone, such as in fracture healing. Softening of metaphyseal bone due to increased osteoclasia associated with exudative inflammation, microfracturing and cyst formation. Cause is unknown; proposed possibilities are distemper virus including vaccine viruses, other viruses and bacterial infections. Vitamin C deficiency is unlikely since dogs can synthesize it in their liver. Boxer dog, 5 months.

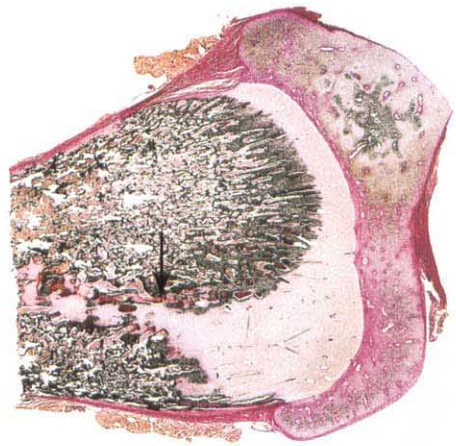


**12-15** Metaphyseal osteopathy (hypertrophic osteopathy or osteodystrophy)
Normal growth plate, disorganized primary spongiosa with abnormally long spicules of remaining cartilage, absence of trabeculae, remnants of necrotic bone, hemorrhage, cyst formation, inflammatory cell infiltration and fibrosis. The sparse irregular trabeculae are due to increased resorption in the secondary spongiosa. Boxer dog, 5 months (see Fig.12-14). Demineralized section. Van Gieson.

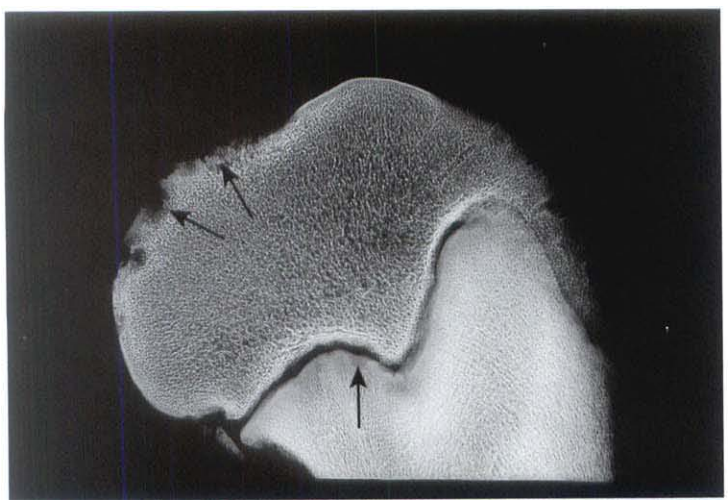


**12-16** Secondary fracture healing
Rib, longitudinal section. Old fracture with dislocated fragments. Extensive external (periosteal) and internal (endosteal) callus formation, both consisting of irregular bone trabeculae and cartilagenous tissue. Foal. Demineralized section. HE.

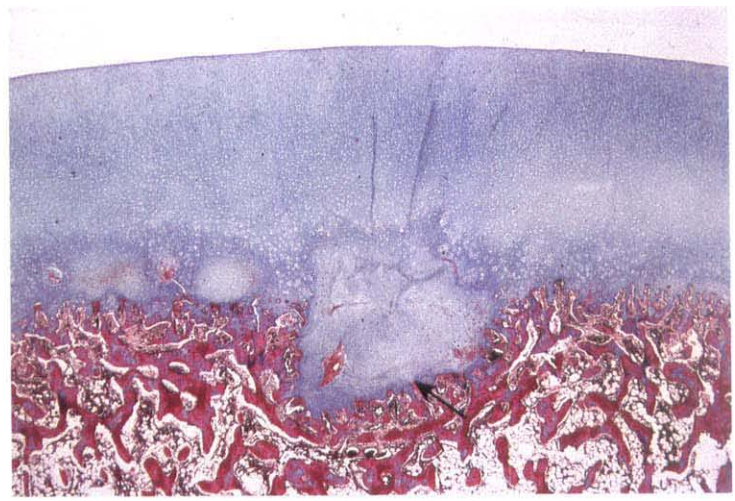
**12-17** Retained enchondral cartilage spur
Distal radius/ulna, sagittal section. Large retained cartilage spur (arrow) representing a remnant of not-for-bone interchanged cartilage in the metaphysis formed by the distal ulnar growth plate. The lesion resulted in retardation of ulnar growth, shortening of the ulna, and bowing of the distal radius (*Radius-curvus* syndrome). Secondary deformation of the ulnar metaphysis is also present. Borzoi dog, 1 1/2 months.



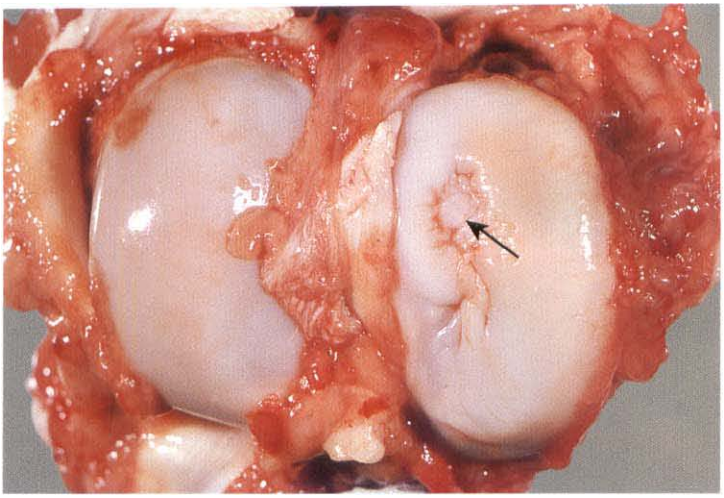
**12-18** Avian tibial dyschondroplasia
Irregular core of non-calcified transitional cartilage tissue (arrow) of the proximal tibial growth plate. Broiler, chicken, 4 weeks. Undemineralized section. Von Kossa's method for calcified tissue.



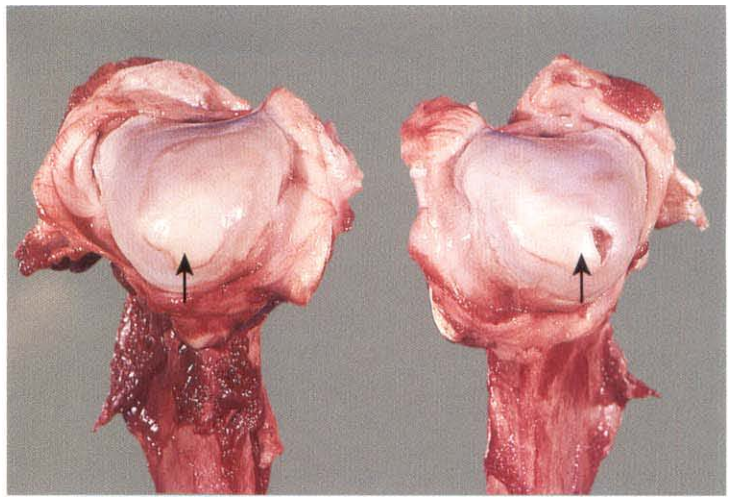
**12-19** Femoral osteochondrosis/dyschondroplasia
Medial femur condyle. X-ray photograph showing loss of mineralized subchondral bone near the joint and near the growth plate (arrows). Pig.



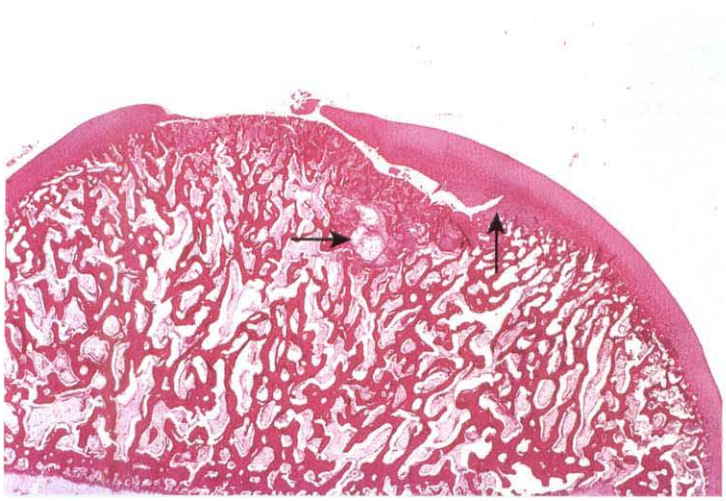
**12-20** Femoral osteochondrosis/dyschondroplasia
Medial femur condyle. Nodular cartilage remnants (arrow) in epiphyseal spongiosa indicating arrest of interchange for bone during growth (dyschondroplasia). Slaughter pig. Azan.



**12-21** Femoral osteochondrosis/dyschondroplasia
Distal femur, articular surface. Remnant lesion from *osteochondrosis dissecans* in the lateral part of the medial femoral condyle (arrow). The defect is filled with reparative fibrocartilaginous tissue. Proliferation of the synovial membrame. Dyschondroplasia/osteochondrosis syndrome. Slaughter pig.

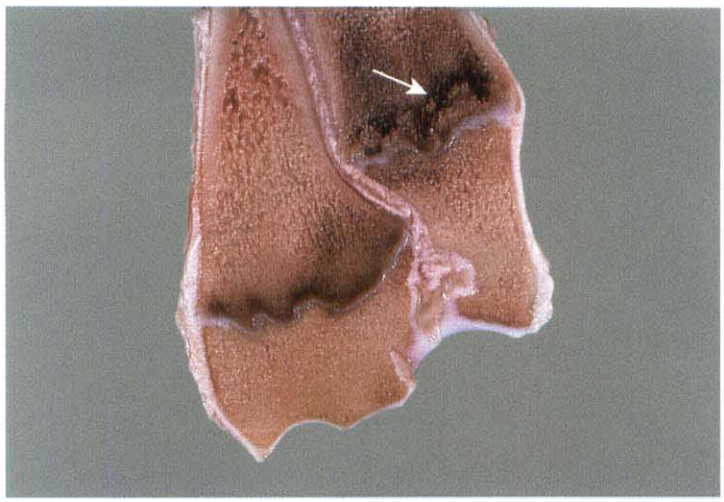


**12-22** Osteochondrosis dissecans
Proximal humeri. Roughly spherical elevated areas of thickened white-colored articular cartilage in the caudal central areas (arrows). In the right-sided humerus, there is loss of a small piece of abnormal cartilage. Dyschondroplasia/osteochondrosis syndrome. Bouvier des Flandres dog, 6 months.

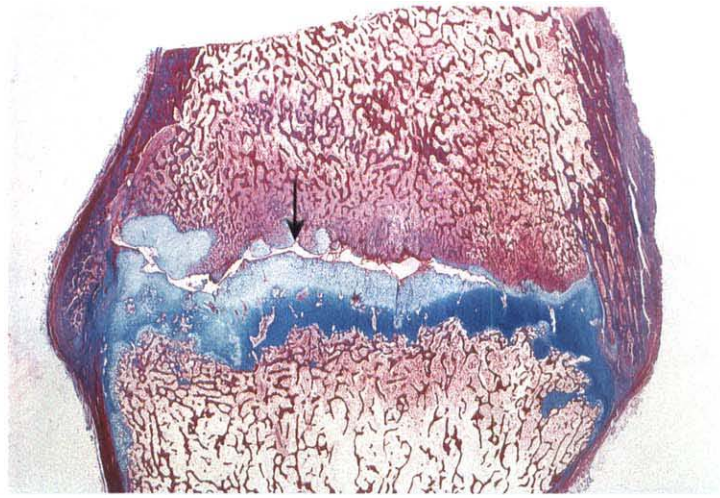


**12-23** Osteochondrosis dissecans
Flap of articular cartilage due to loosening of articular cartilage (right arrow) with reaction of underlying bone showing thickening and cyst formation (left arrow). Pig. Demineralized section. HE.

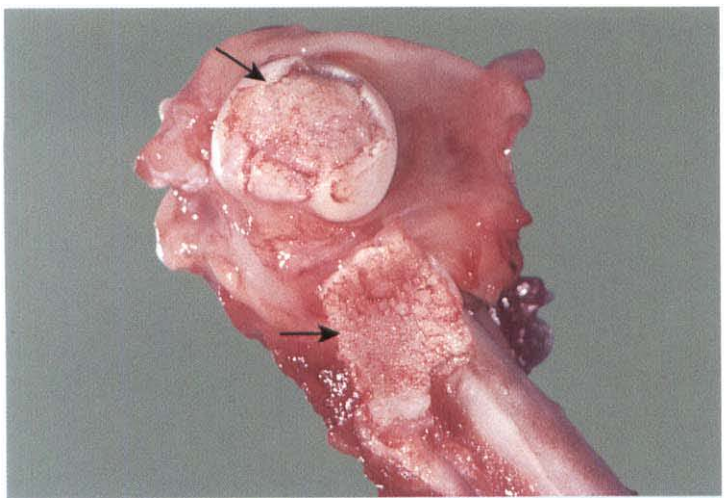
**12-24** Chronic osteochondrosis, brood capsules
Chronic cartilage lesions are associated with formation of regenerative clusters of chondrocytes forming nodules, 'brood capsules'. Pig. Demineralized section. Azan.



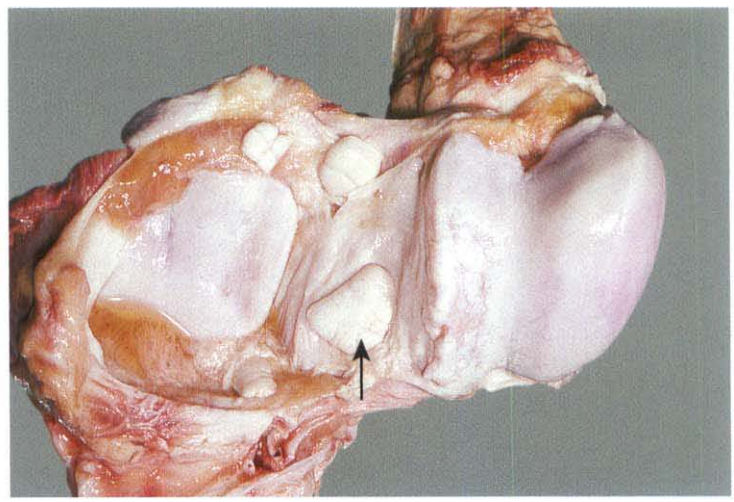
**12-25** Ulnar osteochondrosis
Distal radius/ulna, median section. Disturbed enchondral ossification with fibrosis and lack of trabeculation in the distal ulnar metaphysis (right), due to dyschondroplasia/osteochondrosis in the distal ulnar growth plate cartilage (arrow). Clinical signs of 'Leg weakness'. Slaughter pig.



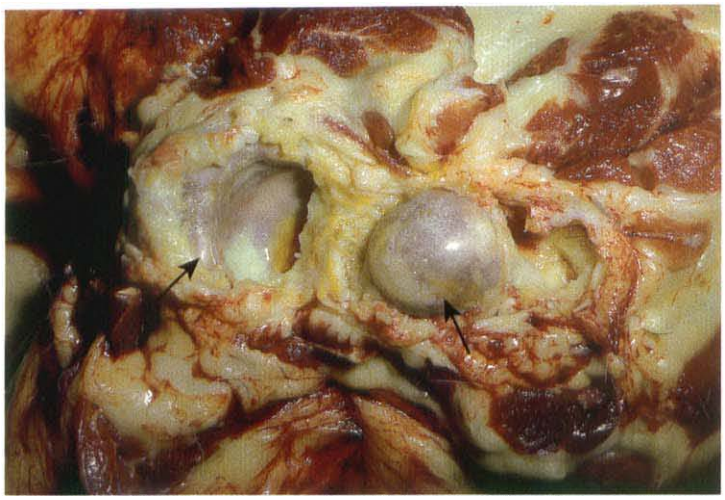
**12-26** Ulnar osteochondrosis
Distal ulna, median section. Disturbed enchondral ossification with lack of trabeculation and cyst formation in the distal ulnar metaphysis (arrow) due to dyschondroplasia/osteochondrosis in the distal growth plate. Clinical signs of 'Leg weakness'. Slaughter pig. Azan.



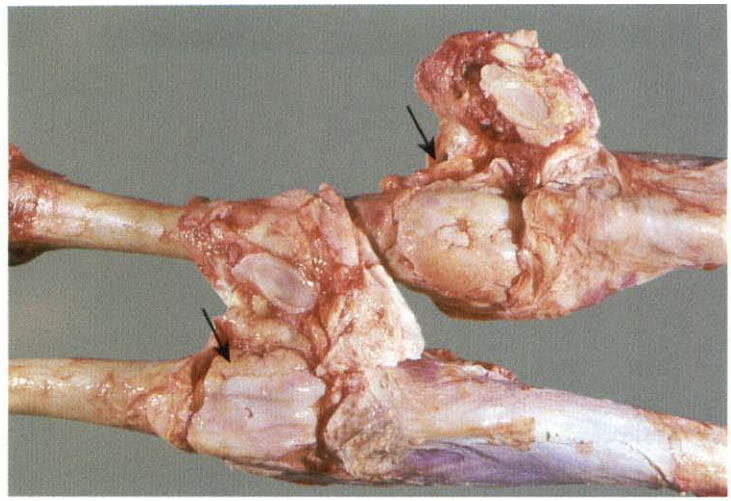
**12-27** Osteochondronecrosis (Legg–Calvé–Perthes disease)
Femoral head with osteochondrosis and necrosis of the superficial bone layer and cartilage (upper arrow) in dwarf breed dogs. The overlying articular cartilage has detached (lower arrow). Toy poodle dog, 6 months.



**12-28** Joint mice
Femoro-patellar joint. Three loose bodies (joint mice, arrow) consisting of cartilage and bone in association with deforming arthrosis of the ridge of the trochlea. Overfilling of the joint cavity with clear, watery synovial fluid. Villous proliferation of the synovial membrane. The patella is on the left. Chronic arthrosis. Horse.

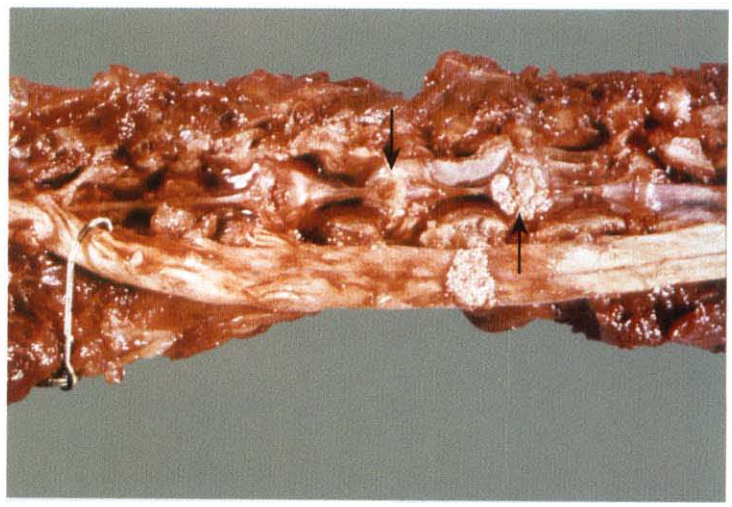


**12-29** Hip dysplasia
Shallow acetabulum with extensively thickened joint capsule (left arrow) and broad, flattened femoral head with erosions (right arrow) in the articular cartilage (deforming arthrosis). German shepherd dog, 1½ years.

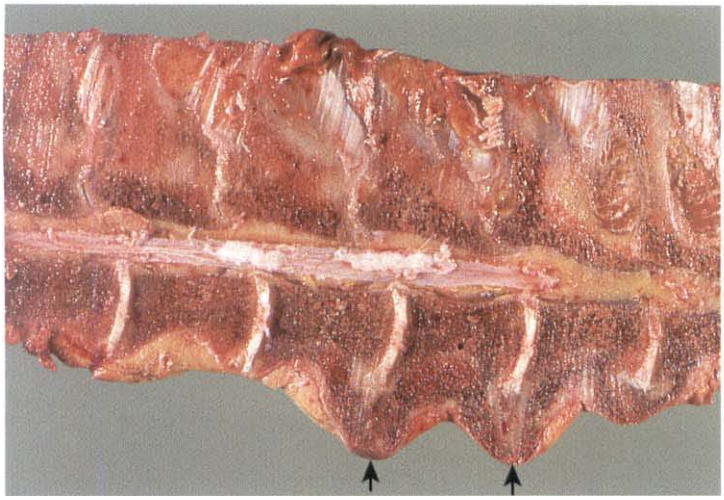


**12-30** Osteoarthrosis/osteoarthritis
Chronic degeneration of articular cartilage of both stifle joints with reactive bone apposition, among others visible as marginal exostoses (arrows). Old dog.

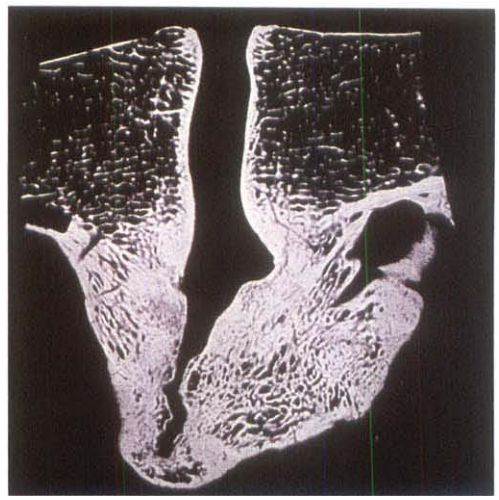
**12-31** Degeneration of intervertebral disc
Intervertebral discs, transverse sections. Normal disc (lower left) with jelly-like center (*nucleus pulposus*) surrounded by the *annulus fibrosus*. Calcification of degenerated *nucleus pulposus* (lower right). Degeneration *of nucleus pulposus* with ruptured *annulus fibrosus* (upper left and right). Dachshund dog, 2 years.



**12-32** Degeneration and herniation of intervertebral disc
Several intervertebral discs have bulging towards the spinal canal (arrows). One of them has ruptured revealing a debris mass originating from a degenerated pulpous nucleus, part of which is sticking to the spinal cord. Dachshund dog, 4 years.



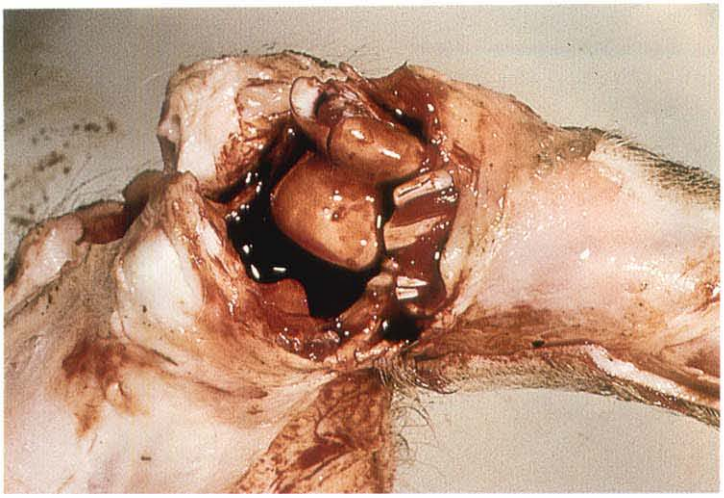
**12-33** Spondylosis
Thoracic vertebrae, sagittal section. Ankylosing spondylosis, fusion of the vertebrae by new bone formation on ventral aspect of vertebral bodies (arrows). Horse, 17 years.



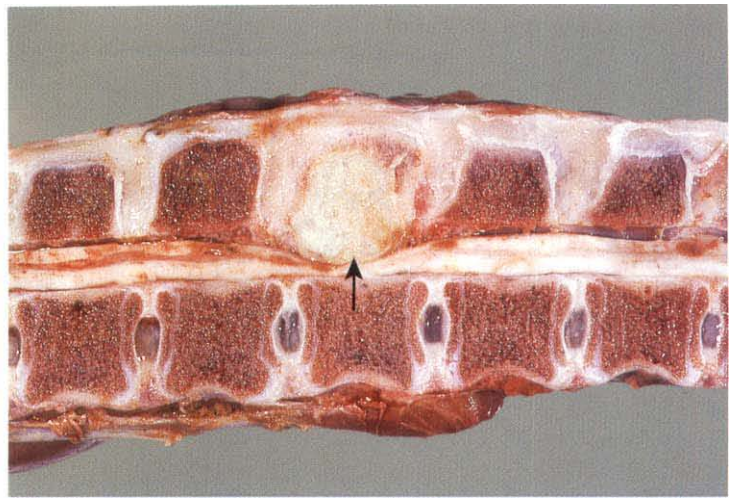
**12.34** Spondylosis
Lumbal vertebral junction, lateral aspect, X-ray photograph. Note ventral bony bridge between two vertebrae. Dog.

**12-35** Hypertrophic (pulmonary) osteoarthropathy (acropachy, Marie-Bamberger's disease)
Macerated specimens of humerus, radius, ulna and metacarpals. Extensive diffuse osteophyte formation (hyperostosis) on the periosteal surfaces, predominantly of the metacarpals and radius/ulna. Extensive lung tumors were present. Dog.

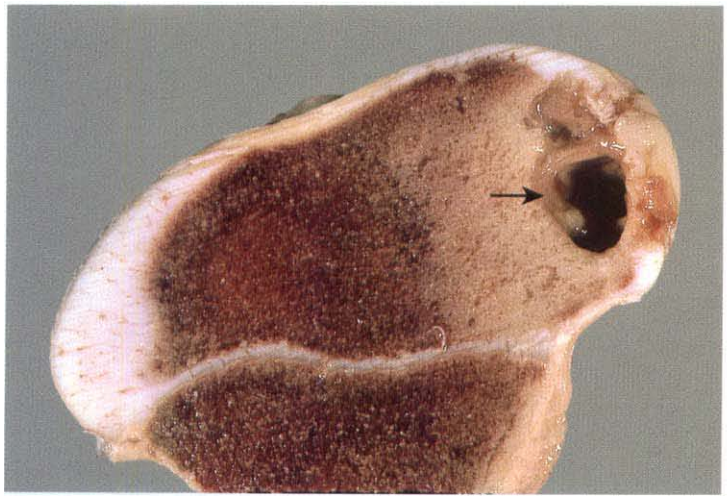
**12-36** Hypertrophic (pulmonary) osteoarthropathy
Radius, transverse section. Periosteal hyperostosis; the newly formed trabecular bone, perpendicular to the surface, is clearly distinguishable from the original cortex (compact bone). Dog had extensive lung tumors. Dog. Demineralized section. HE.



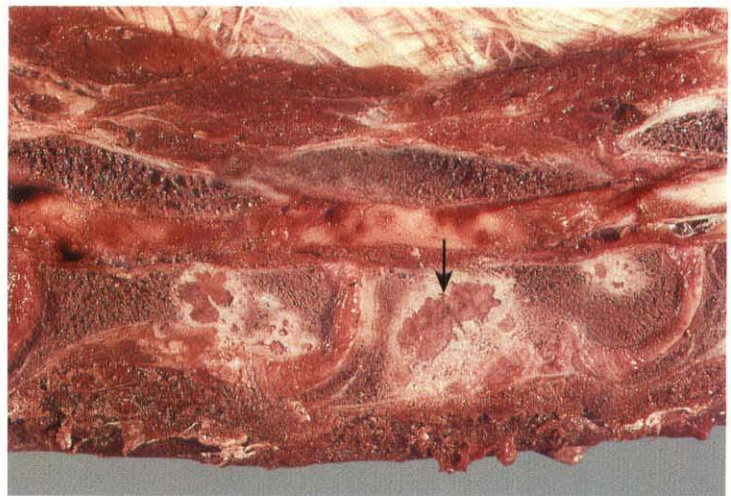
**12-37** Hemarthros
Tarsocrural joint. The joint cavity is filled with blood. Warfarin® poisoning (cumarine-derived vitamin K antagonist). Fattening pig.



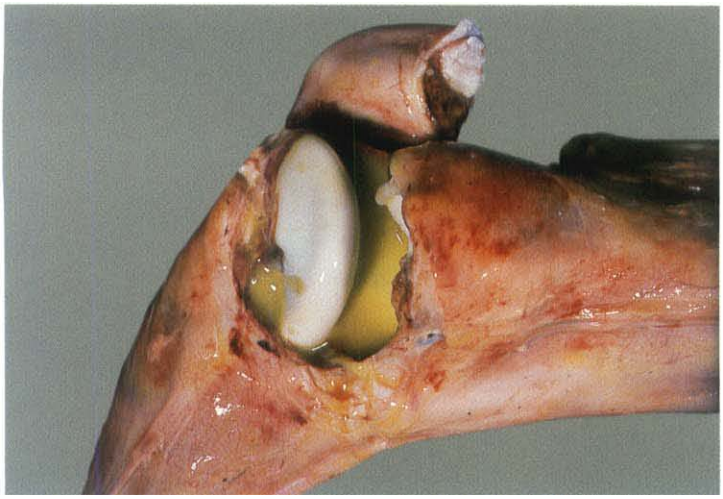
**12-38** Suppurative osteomyelitis
Spine, sagittal section. Large abscess in the spinal process of a thoracic vertebra resulting in compression of the spinal cord (arrow), secondary to bacterial infection of tail wounds (cannibalism). Fattening pig with paralysed hindquarter.



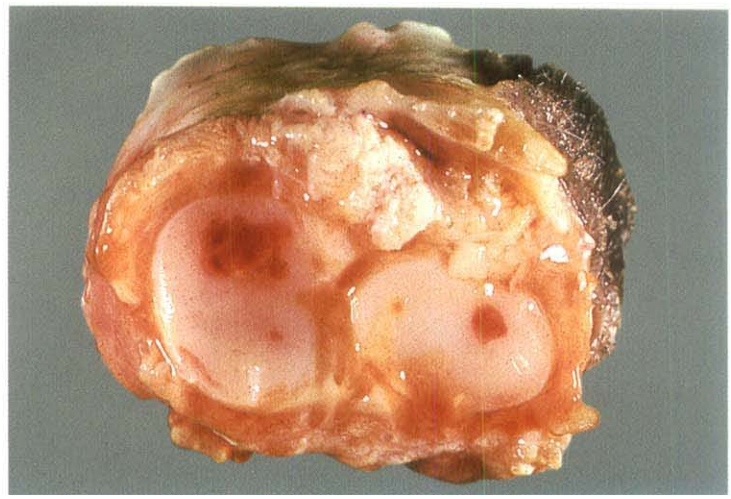
**12-39** Suppurative osteomyelitis
Medial femoral condyle, sagittal section. Large cystic lesion (arrow) with necrotizing and suppurative osteomyelitis in the subchondral bone. Osteolysis and inflammation extending into the joint cartilage. Reactive osteosclerosis surrounds the cyst. *Rhodococcus equi* infection. Foal.



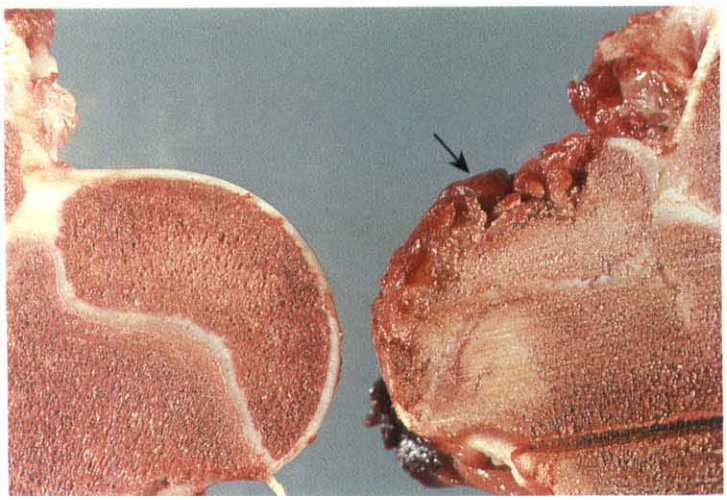
**12-40** Granulomatous osteomyelitis
Spine, sagittal section. Various granulomatous lesions in vertebral bodies. Avian tuberculosis (*Mycobacterium avium*). Pony.



**12–41** Acute arthritis
Talocrural joint. Joint cavity is filled with serofibrinous exudate, with a hyperemic and edematous synovial membrane. *Escherichia coli* infection. Foal.

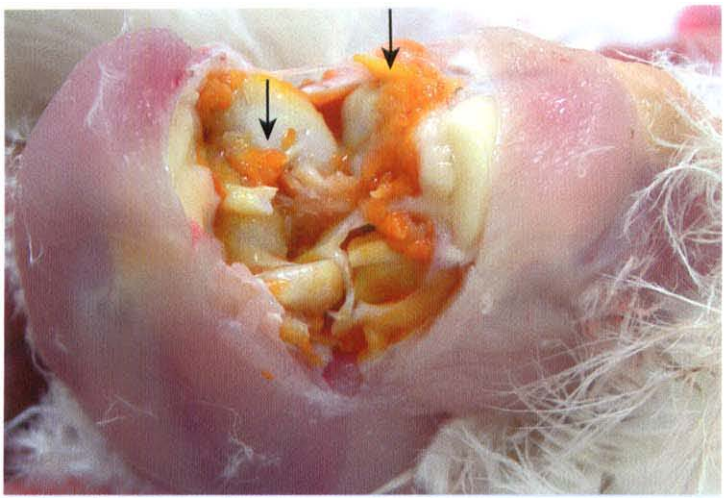


**12–42** Subacute arthritis
Carpal joint. Small and large ulcers on articular cartilage, filled with proliferation of hyperemic granulation tissue (*pannus*); swollen and edematous synovial membrane with fibrin deposition. Calf.

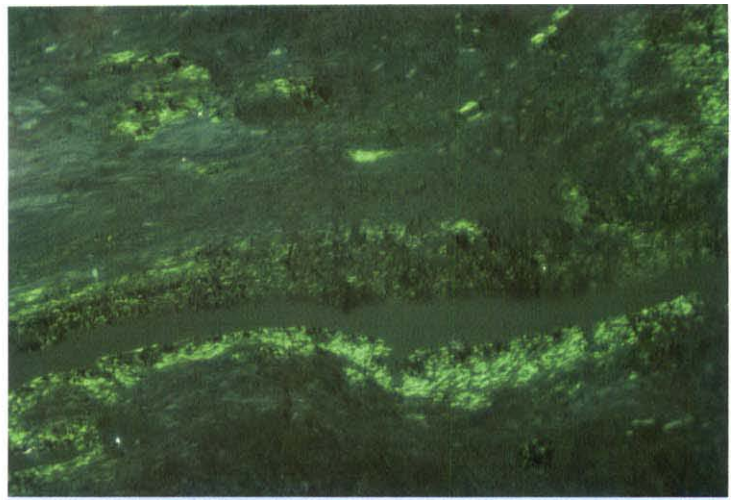


**12–43** Deforming arthritis
Femoral joint, sagittal section. Unilateral total destruction of joint cartilage (arrow) due to septic arthritis (right). Compared to normal joint (left). *Streptococcus zooepidemicus* infection. Foal, 10 weeks.

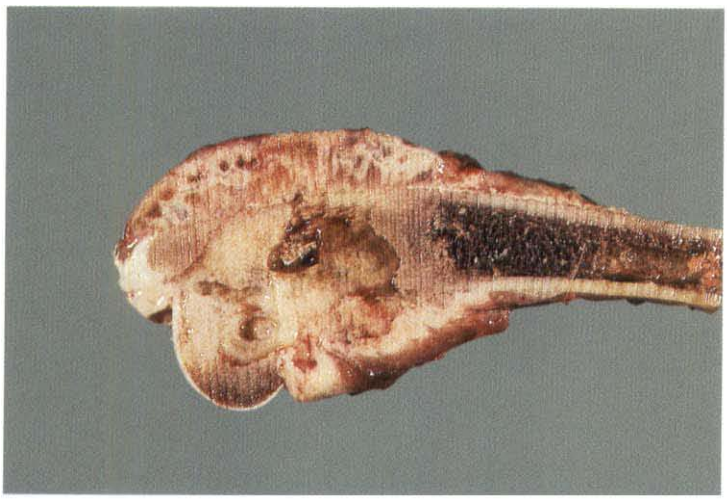
**12–44** Chronic arthritis
Stifle joint, submerged in water. Enlargement of the villi of the synovial membrane due to chronic inflammation and hyperplastic changes. Pig.



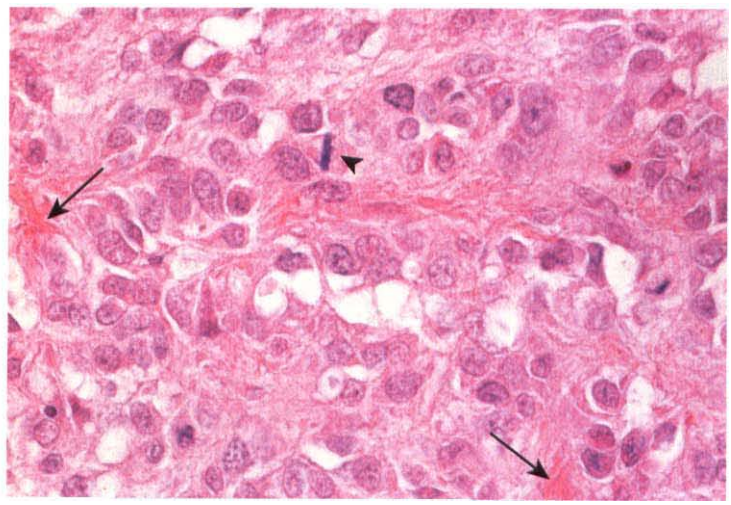
**12-45** Avian amyloid arthropathy
Overfilled joint cavity with orange-colored amyloid (arrows). *Gallinae* often develop amyloid deposits in joints with chronic arthritis. *Enterococcus faecalis* infection. Commercial 'silver' layer chicken, 15 weeks.



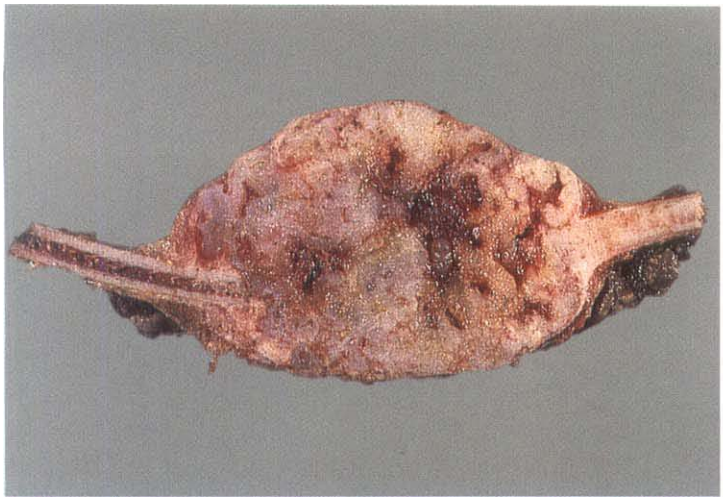
**12-46** Avian amyloid arthropathy
Green colored, birefringent material indicative for amyloid. *Enterococcus faecalis* infection. Commercial 'brown' layer, 10 weeks. Congo red stain.



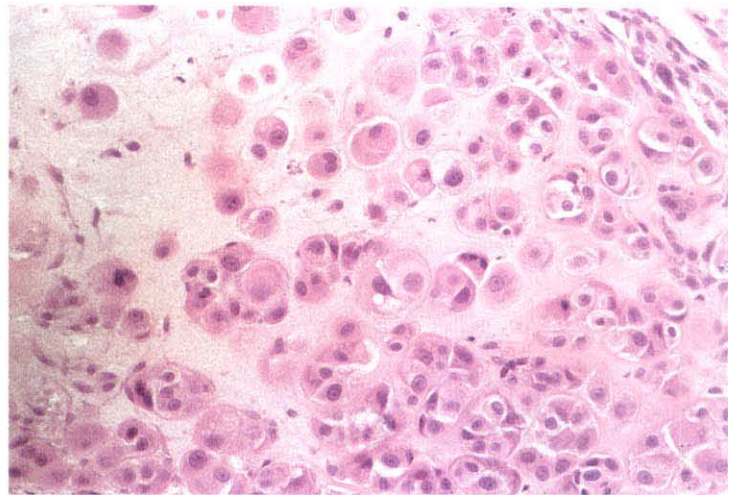
**12-47** Osteosarcoma
Proximal humerus, sagittal section. Irregular tumor mass in the metaphysis has replaced the original bone and has infiltrated and destroyed the cortical bone and surrounding tissues. The tumor had grown into the epiphysis. Marked endosteal and periosteal new reactive bone. Airedale terrier dog, 9 years.



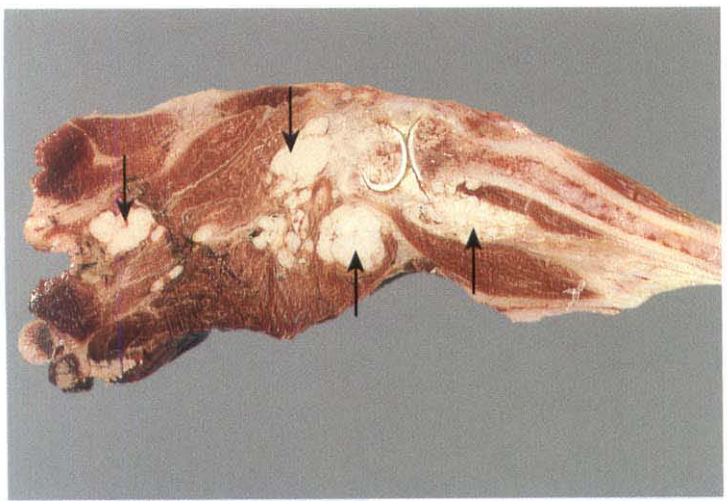
**12-48** Osteosarcoma
Polymorphic neoplastic osteogenic cells that have produced some small irregular, homogeneous, eosinophilic masses of osteoid (arrows). Mitotic figure (arrowhead). Bouvier de Flandres dog, 7 years. Undemineralized section. HE.



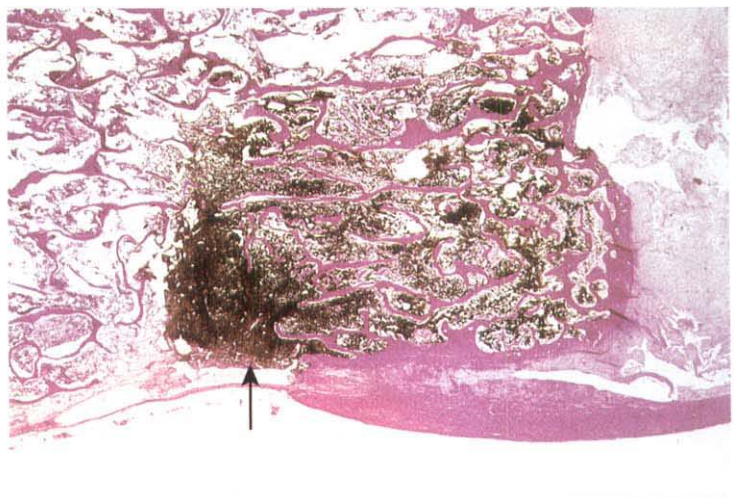
**12-49** Chondrosarcoma
Rib, costochondral junction, sagittal section. Hyaline proliferative tumor mass with necrosis has replaced the original bone and has grown outwards. German shepherd dog.



**12-50** Chondrosarcoma
Polymorphic neoplastic chondrocytes. Dog. HE.

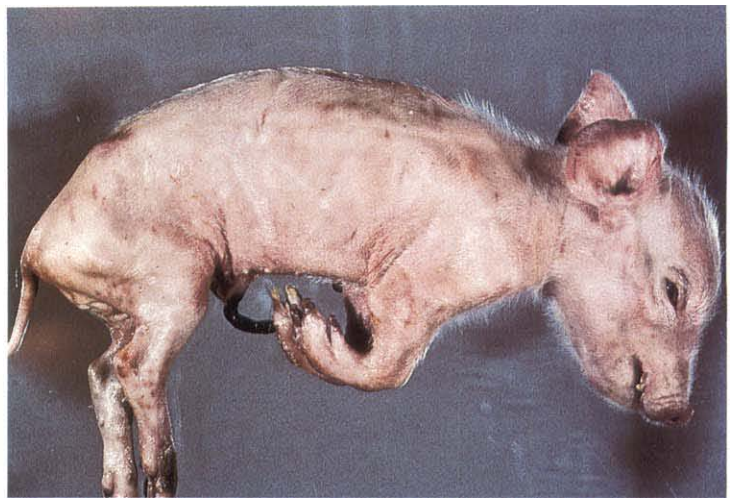


**12-51** Synovial sarcoma
Stifle joint, sagittal section. Tumors in and around joint cavity with metastases (arrows). The articular surface remained free of the malignancy. Dog.

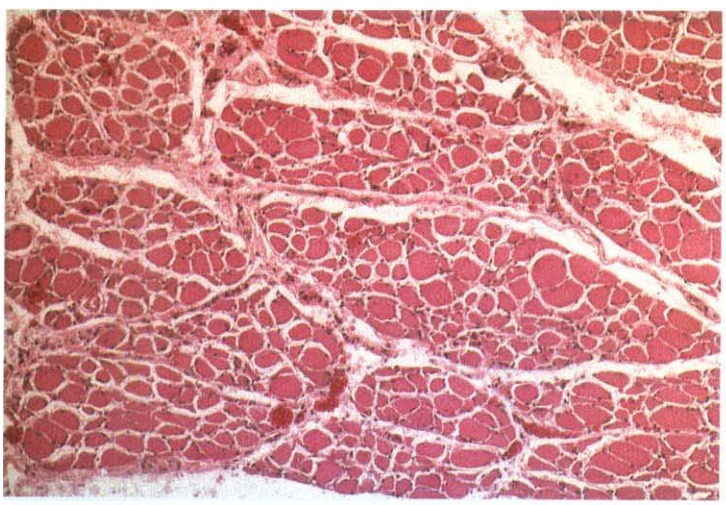


**12-52** Metastatic melanotic bone tumor
Thoracic vertebral body. Intertrabecular growth of melanin-producing tumor cells and osteolysis of the original bone tissue. Primary oral malignant melanoma. Note the black-stained tumor masses (arrow). Dachshund dog. Demineralized section. HE.

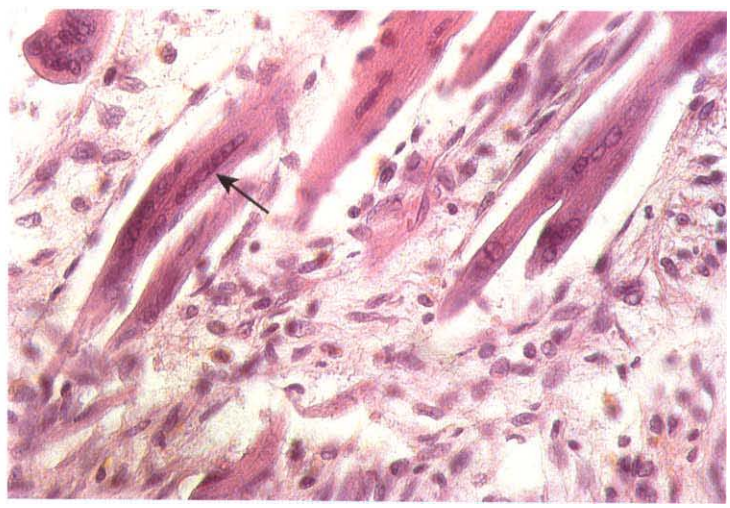
**12-53** Myofibrillar hypoplasia (congenital splayleg)
The rear legs are extended forward and laterally as a result of transient myofibrillar hypoplasia. To prevent further spreading of the legs, they are taped together. Piglet, one day.



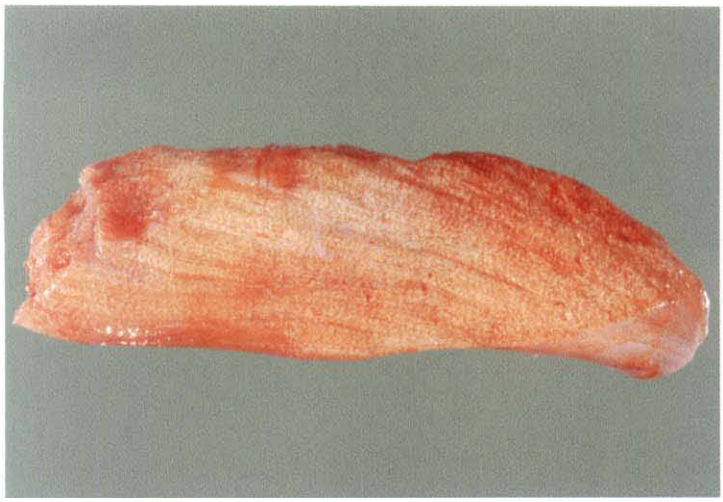
**12-54** Congenital articular rigidity (*arthrogryposis congenita*)
Flexion and articular rigidity of the forelimb joints. Piglet.



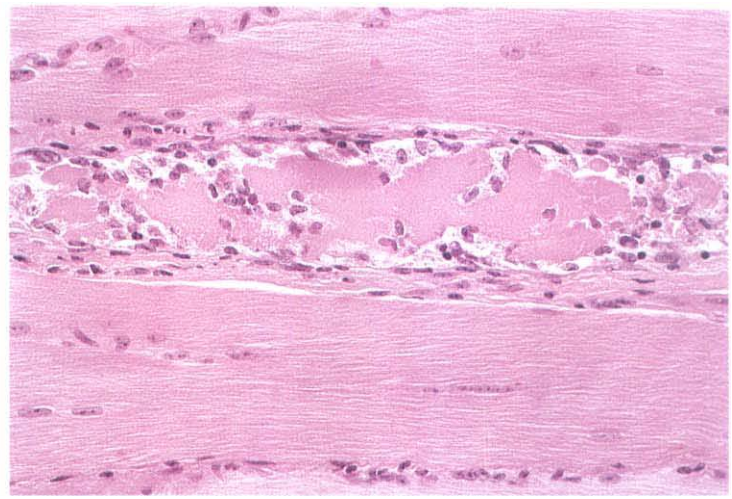
**12-55** Neurogenic muscular atrophy
Cross-section of the dorsal cricoarytenoid muscle. All fascicles contain atrophic angular muscle fibers between fibers with normal diameter and hypertrophied fibers. Hereditary laryngeal paralysis, a disease associated with neuronal loss in brain stem nuclei. Bouvier des Flandres dog, 6 months. HE.



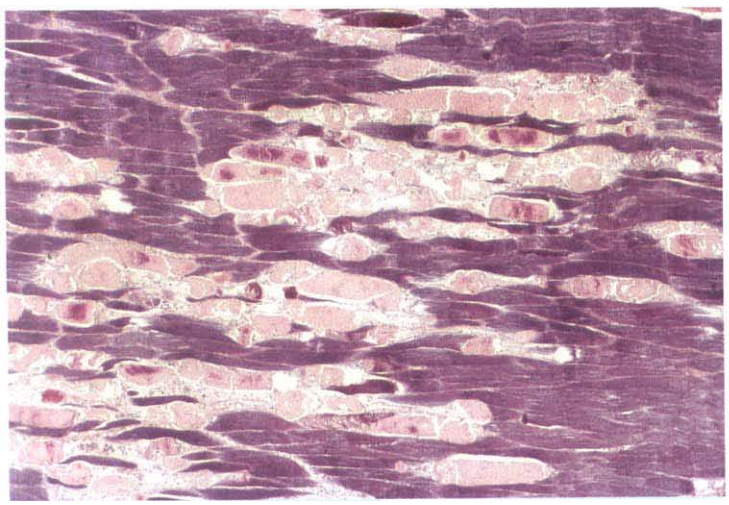
**12-56** Muscular regeneration
Characteristic row of centrally located nuclei (arrow) in regenerating muscle cells after repair of a wound. Dog. HE.



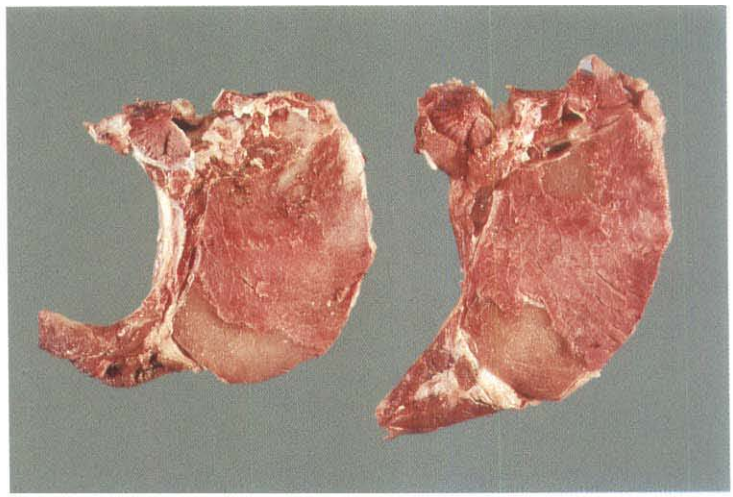
**12-57** Nutritional myodegeneration
Longitudinal section. Swollen, coarse-structured, pale, soft muscle tissue (white muscle disease). Histologically, a variable degree of degeneration was present in the muscle. Vitamin E deficiency. Donkey foal.



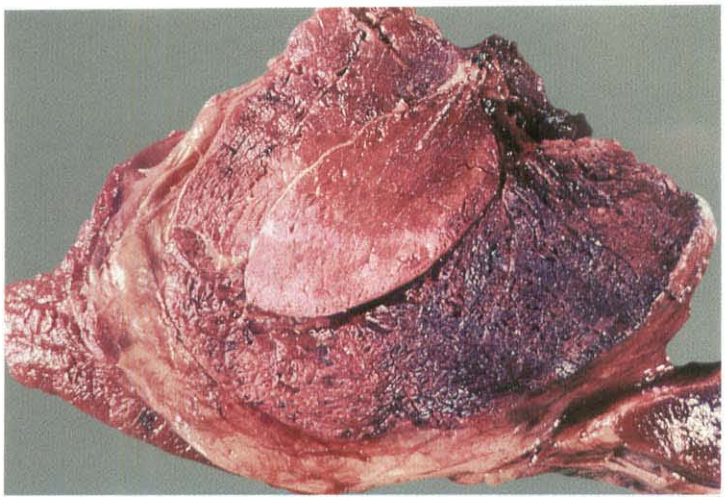
**12-58** Hyaline degeneration
Homogeneous, eosinophilic, fragmented muscle fiber undergoing phagocytic removal. Nutritional deficiency (selenium/vitamin E). Calf. HE.



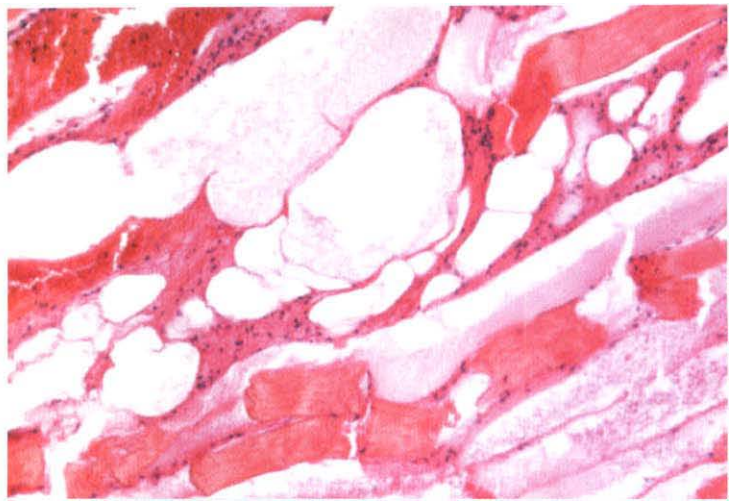
**12-59** Exertional rhabdomyolysis
Muscle with pale areas containing necrotic muscle fibers with loss of cross-striation and loss of purple staining of myofibrillary cytoplasm. Exertional rhabdomyolysis after tying-up. Horse. Phosphotungstic acid hematoxylin.



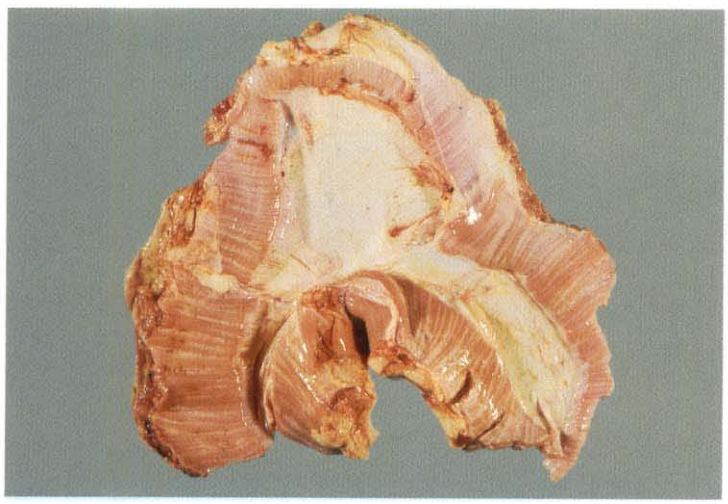
**12-60** Back-muscle necrosis
Longissimus muscle, transverse section. Sharply demarcated, elevated, pale, dull areas of coagulation necrosis. Clinically, signs of 'Banana disease' after transport to the abattoir. Malignant hyperthermia/stress syndrome. Slaughter pig.



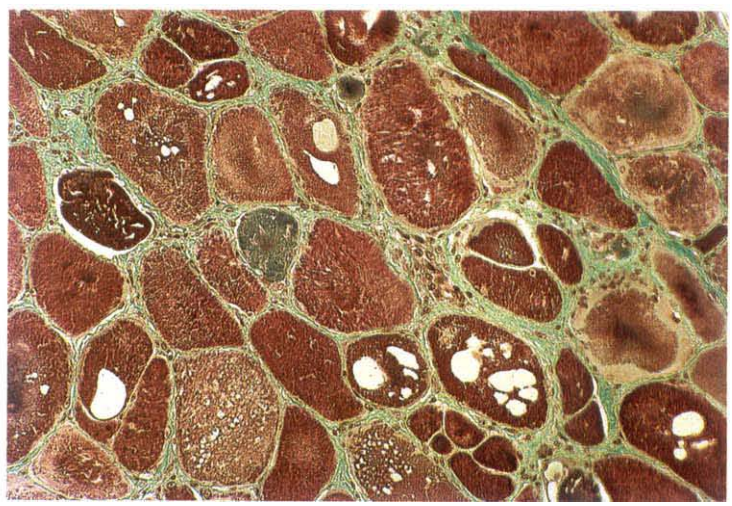
**12-61** Blackleg (gangrenous myositis)
Pelvic muscle, cut surface. The muscle is dark red in color, dry, friable, and porous due to the presence of gas bubbles. The fascia is edematous. *Clostridium chauvoei* infection. Cow.



**12-62** Blackleg (myositis)
Hindquarter muscle with hemorrhage, necrosis, edema and gas. *Clostridium chauvoei* infection. Cow. HE.

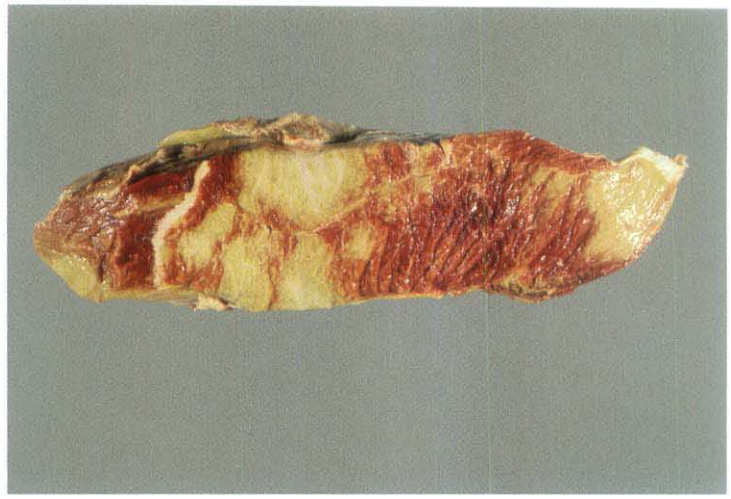


**12-63** Muscular dystrophy
Swollen, pale-colored diaphragmatic muscular tissue. Hereditary glycogenosis. Dog.

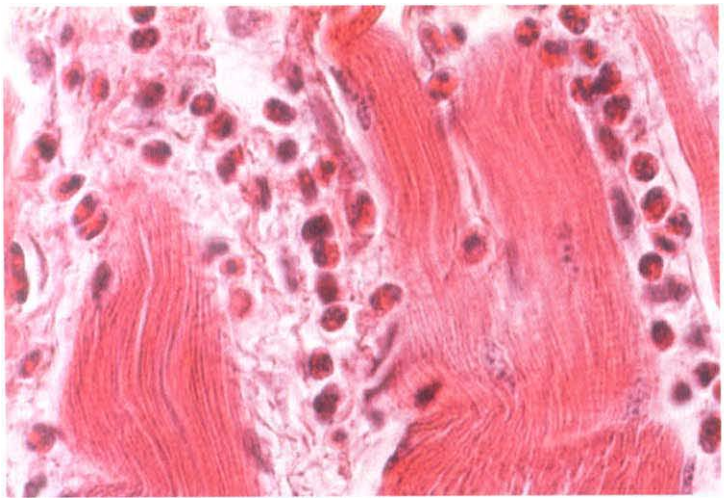


**12-64** Muscular dystrophy
Diaphragmatic muscle, transverse section. Great variation in muscle fiber diameter, vacuolar degeneration, fiber splitting, central cores, phagocytosis, endomysial fibrosis. Bovine familial muscular dystrophy. Meuse-Rhine-Yssel cow, 5 years. Gomori's trichrome.

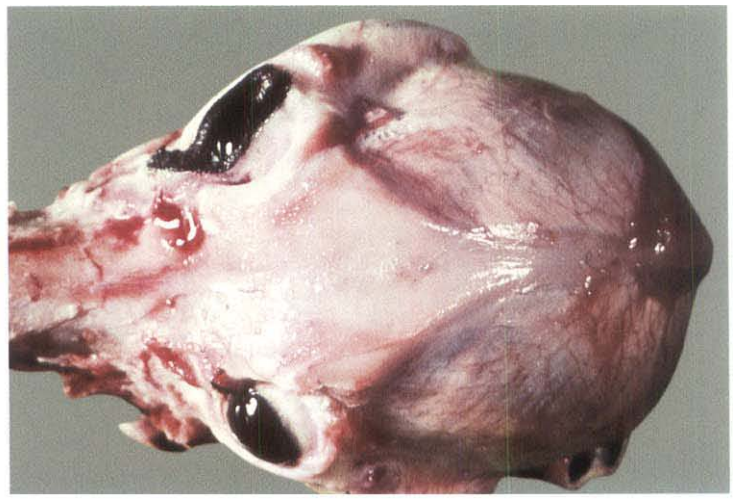
**12-65** Muscular steatosis (*pseudohypertrophia lipomatosa*)
Replacement of muscle by adipose tissue. Slaughter cow.



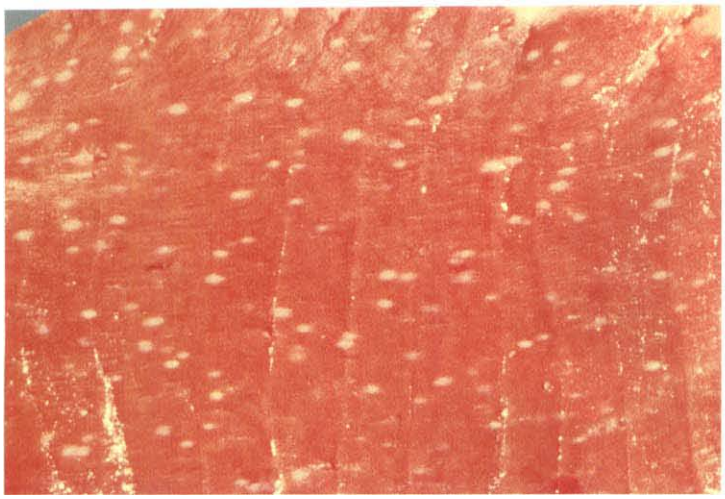
**12-66** Bovine eosinophilic myositis
Semitendinosus muscle. Rather well circumscribed, elevated, pale-greenish areas, indicative of infiltration of many eosinophilic granulocytes. Cow.



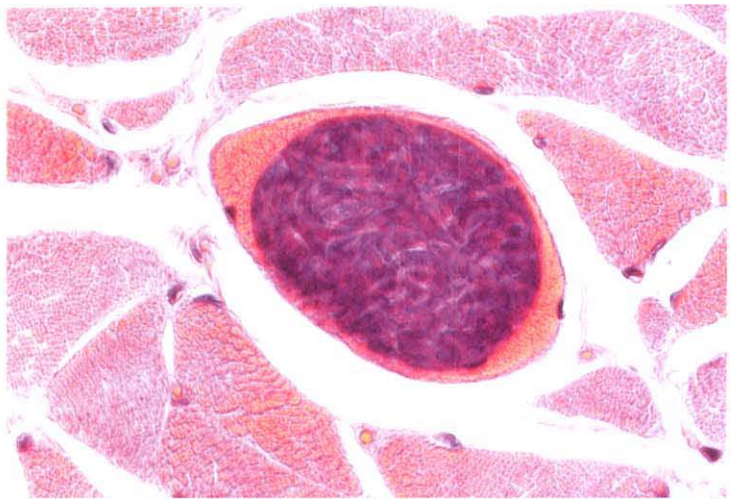
**12-67** Bovine eosinophilic myositis
Semitendinosus muscle. The inflammatory pattern is dominated by eosinophilic granulocytes. Cow. HE.



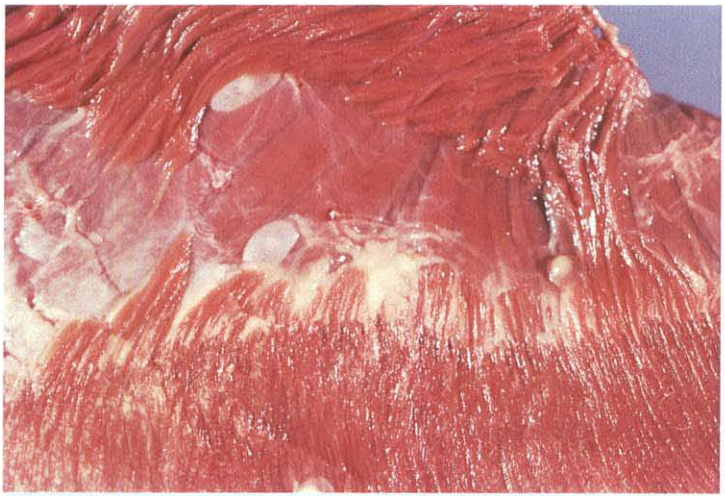
**12-68** Canine eosinophilic myositis
Atrophy of masseter muscles due to chronic eosinophilic myositis. German shepherd dog.



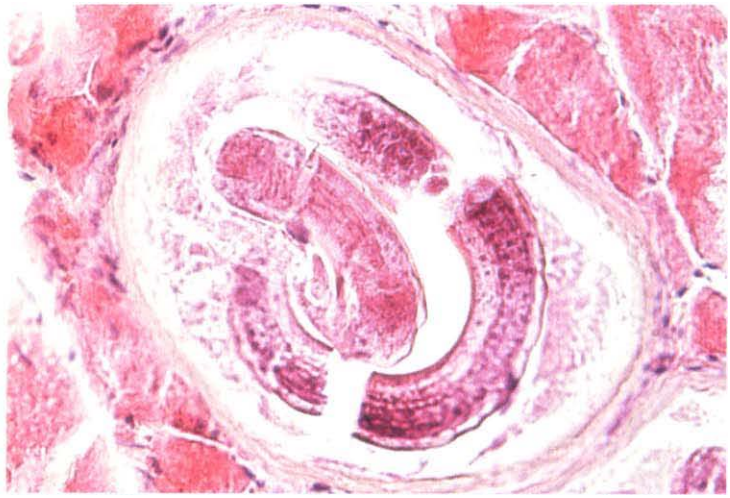
**12-69** Sarcosporidiosis
Skeletal muscle. Multiple small white foci due to inflammatory reactions developing after death of sarcosporidial cysts. Cow.



**12-70** Sarcosporidiosis
Sarcosporidial pseudocyst in muscle fiber. In cattle and pigs such histological cysts (without inflammatory reaction) give no gross features and are overlooked. Lesions appear when the parasite dies and cell necrosis and an inflammatory reaction develop. In sheep cysts may become larger and then they are grossly recognizable (*Sarcocystis gigantea* (syn. *S. ovifelis*) infection). Sheep. HE.



**12-71** Cysticercosis
Masseter muscle. Ellipsoidal, 0.5–1 cm, cystic structures, with clear contents and with a white scolex in each. *Cysticercus inermis* infection. Cow.



**12-72** Trichinosis
*Trichinella spiralis* in muscle fiber. Haematoxylin-safranin. Wild boar.

Chapter 13

# The skin



## THE SKIN

The skin consists of epidermis, dermis, adnexa (hair follicles, sebaceous glands, sweat glands) and subcutis.

Gross evaluation of the skin is synonymous with a clinical or dermatological evaluation of the skin.

Reactions of the skin may result in primary or secondary lesions:

A *primary lesion* may be defined as the initial lesion that develops as a direct reflection of an underlying disease. These include:

- macule or patch (circumscribed flat area of any size, usually characterized by its color);
- papule (elevated solid area, ≤ 5 mm) or
- nodule (elevated solid area, ≥ 5 mm) or
- plaque (elevated flat-topped area, ≥ 5 mm);
- vesicle (fluid-filled raised area, ≤ 5 mm); or
- bulla (large blister; fluid-filled raised area, ≥ 5 mm);
- pustule (circumscribed, pus-filled, raised area);
- wheal (itchy, transient, elevated area with variable blanching or erythema, due to dermal edema); and
- cyst (circumscribed cavity, filled with clear fluid, horn or sebaceous material).

Identification of primary skin lesions and assessing their diagnostic significance is an essential step in formulating a diagnosis or differential diagnoses.

*Secondary lesions* evolve from primary lesions or are induced by external factors such as trauma. Secondary lesions include epidermal collarette, scar, excoriation, erosion or ulcer, lichenification, and callus.

A number of gross lesions may be *primary* or *secondary* such as alopecia, scales, crusts, comedones, or pigmentary changes.

At the histological level, the general reaction patterns of the skin can be divided according to the *localization* or according to the *type of lesion* (mainly inflammation and neoplasia). Based on localization, the reaction patterns can be divided into those affecting the epidermis, dermis, hair follicles, sebaceous glands, sweat glands, and subcutis.

## Epidermis

The most common lesions are:

- epidermal hyperplasia;
- epidermal atrophy;
- hypergranulosis, hyperkeratosis, parakeratosis and dyskeratosis;
- epidermal edema;
- acantholysis; and
- other epidermal lesions.

### Epidermal hyperplasia

Epidermal hyperplasia is an increase in the number of nucleated cells. *Acanthosis* is often used as a synonym for epidermal hyperplasia although, strictly speaking, acanthosis refers to hyperplasia of the stratum spinosum.

### Epidermal atrophy

Epidermal atrophy is uncommon.

### Hypergranulosis, hyperkeratosis, parakeratosis and dyskeratosis

*Hypergranulosis* denotes an increase in the width of the stratum granulosum.

*Orthokeratotic hyperkeratosis*, often referred to as hyperkeratosis, indicates an increase in width (hyperplasia) of the stratum corneum in which the process of cornification has occurred, although the quality of the keratin may be abnormal.

In *parakeratotic hyperkeratosis*, usually shortened to parakeratosis, the mode of keratinization has been disturbed, characterized by retention of the nuclei of the keratinocytes in the stratum corneum.

*Dyskeratotic keratinocytes* with hypereosinophilic cytoplasm and degeneration of the nucleus are individual (groups of) cells below the stratum granulosum that have undergone abnormal and premature keratinization. They are difficult to distinguish from apoptotic cells.

### Epidermal edema

*Epidermal edema* can be intercellular between keratinocytes (spongiosis) or intracellular; the latter representing a degenerative change of epithelial cells. Fluid-filled spaces within the epidermis are referred to as microvesicles, vesicles or bullae.

### Acantholysis

Acantholytic keratinocytes, identified as rounded cells with hypereosinophilic cytoplasm and morphologically normal nuclei, are formed by the loss of intercellular connection between viable keratinocytes. This process of *acantholysis* may be mediated by immune mechanisms, as in *pemphigus foliaceus*.

### Other epidermal lesions

Other epidermal lesions include dysplasia, exocytosis (the migration of leukocytes into the epidermis), necrosis, and hyper- and depigmentation.

## Dermis

*Dermal changes* may consist of:

- an increase or decrease in collagen;
- collagen degeneration which includes dystrophic mineralization and the deposition of various substances such as amyloid, lipid, or glycosaminoglycans as in mucinosis.

## Hair follicles

*Hair follicles* may show keratosis, hypertrophy, atrophy, or dysplasia.

In some conditions the hair follicles show *excessive trichilemmal keratinization*, also referred to as *'catagen arrest follicles'*.

## Sebaceous glands

*Sebaceous glands* may show hyperplasia or atrophy.

## Sweat glands

Pathology of apocrine sweat glands is rare and they are often activated in dermatitis.

## Pattern analysis of inflammatory skin disease

Inflammation may involve each of the components of the skin and may be classified on the basis of:

- the affected structure;
- type of inflammatory cell(s) present;
- lesion distribution; and
- chronicity.

In diagnostic veterinary dermatopathology, *pattern analysis of inflammatory skin disease* was developed to aid in the histological diagnosis of skin disease. The pattern selected to characterize an individual disease is considered the most typical and therefore the most diagnostic. However, one specific condition may exhibit different patterns at successive stages of its development whereas several different diseases may manifest the same pattern. Furthermore, some patterns are more diagnostic than others. When degenerative diseases are included, the following major patterns are recognized (variations may occur between different textbooks):

- *Perivascular dermatitis*: this is the most common and the least diagnostic pattern. Lesions are characterized by vasodilatation of dermal blood vessels and perivascular inflammatory cell infiltration.
- *Interface dermatitis*: in this pattern superficial dermal inflammation is orientated tightly to and often obscuring

the dermal–epidermal junction. The pathogenetic mechanism of this pattern of inflammation reflects immune-mediated damage to epidermal basal cells, the basement membrane or melanocytes.

- *Intraepidermal* or *subepidermal vesicular* and/or *pustular dermatitis*: lesions are characterized by intraepidermal vesicles, bullae and/or pustules or by separation of the dermis from the epidermis without/with pustule formation, respectively. Pustules may contain variable types of inflammatory cells, but predominantly leukocytes.
- *Nodular* and/or *diffuse dermatitis*: this pattern is characterized by multifocal nodular inflammation, which tends towards confluence or a diffuse pattern.
- *Vasculitis*: small or large vessels are the target of the inflammatory response. Distinguishing between primary and secondary cutaneous vasculitis may be difficult. Most cutaneous vasculitides in dogs and cats affect small vessels.
- *Folliculitis, furunculosis* and *sebaceous adenitis*: folliculitis may be luminal or/and mural; furunculosis signifies the rupture of hair follicles due to inflammatory damage and usually is the result of luminal folliculitis; sebaceous adenitis may be a primary condition in the dog and cat while sebaceous glands also may be caught up in conditions causing folliculitis and/or furunculosis.
- *Panniculitis*: a common reaction pattern characterized by inflammation of the subcutaneous fat tissue that lies between the dermis and the fascia.
- *Atrophic dermatosis*: in this non-inflammatory pattern, atrophic changes in hair follicles and other adnexa and, less commonly, in the dermis and epidermis are present.

## *Neoplasia*

Neoplasms of the skin are frequently diagnosed in domestic animals and they are broadly classified as:

- epithelial;
- mesenchymal; and
- melanocytic.

In recent years, immunohistochemical characterization of cytoplasmic or surface markers has become a powerful tool in the diagnosis of several types of cutaneous tumors.

### Epithelial neoplasms

*Epithelial neoplasms* are separated into epidermal, follicular, sebaceous, sweat gland and nailbed epithelial tumors.

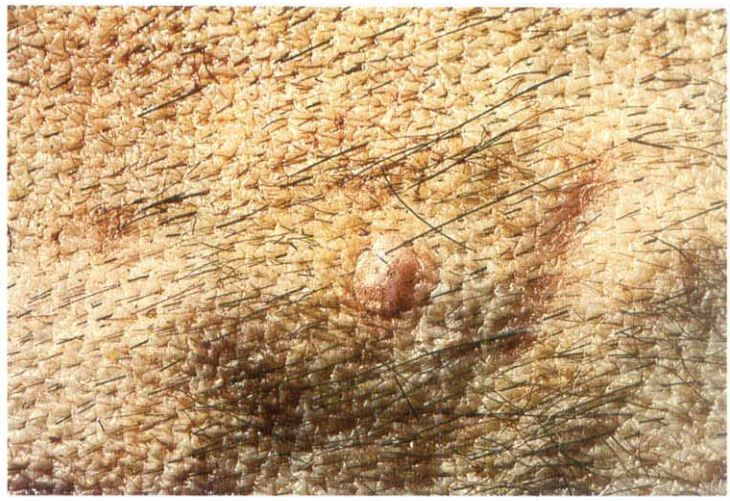
### Mesenchymal neoplasms

*Mesenchymal neoplasms* include spindle cell tumors, vascular tumors and round cell tumors. *Round cell tumors* comprise a heterogenous group of tumors that have in common more or less spherical cells. This group includes histiocytoma and cutaneous histiocytosis, mast cell tumor, lymphoma, plasmacytoma and transmissible venereal tumor.

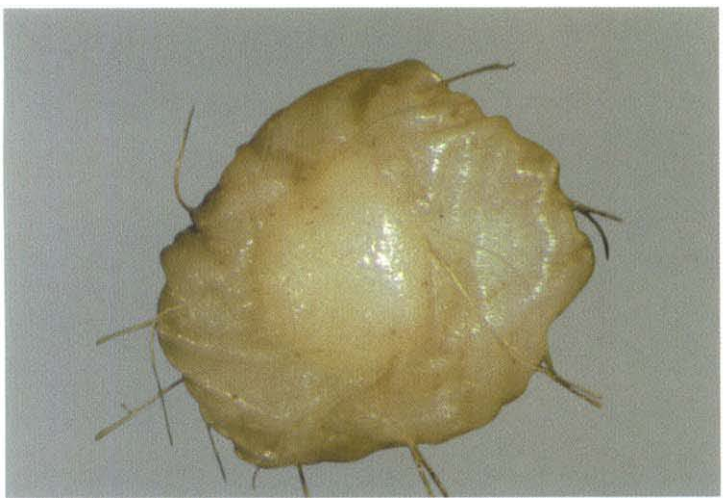
### Melanocytic neoplasms

Melanocytic cells are derived from the neural crest. The *melanomas* may exhibit melanin containing cells, but *amelanocytic* melanomas also occur. The cells may show a rather epithelial pattern, but in other melanomas spindle cells as in mesodermal tumors dominate. Melanomas are mostly seen in dogs, cats and horses.

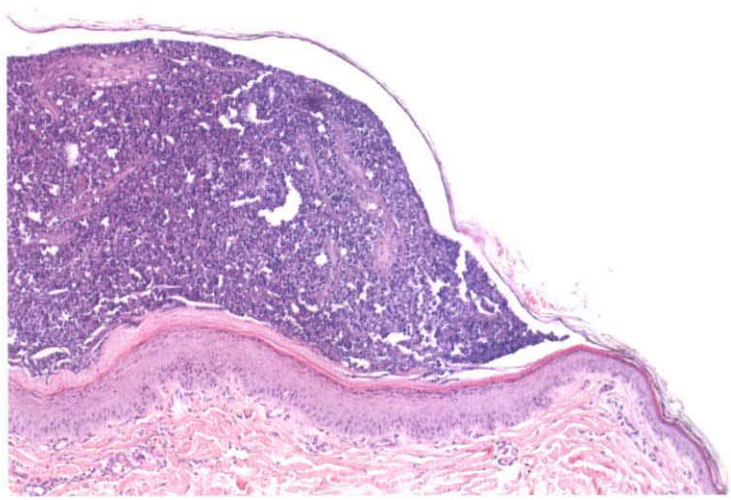
**13-1** Macules
Inguinal region. Non-elevated spots in the skin characterized by a difference in color when compared to the surrounding skin. Several brown-black pigmented macules are present. Macules may also occur due to a lack of pigment in a dark skin or by hyperemia. Dog.



**13-2** Papule
Partially shaved skin. A solid elevation up to about 5 mm in diameter due to a process in the epidermis (epidermal papule) or dermis (dermal papule). Such lesions may be due to intercellular or intracellular edema, or the proliferation of epidermal or dermal cells (inflammation, neoplasia). Larger lesions are called nodules (see Fig. 13-5). Dog.



**13-3** Vesicle/pustule
A single vesicle or pustule in a skin biopsy of a dog. Vesicles are less than 5 mm in diameter and may be intra-epidermal (subcorneal or suprabasal) or subepidermal, contain fluid and can be formed by intercellular edema, intracellular edema (ballooning degeneration) or lack of cohesion between epithelial cells (acantholysis). Pustules contain inflammatory cells, especially granulocytes. Dog.



**13-4** Pustule
A subcorneal pustule filled with neutrophils is elevated above the surface of the skin. Suspected subcorneal dermatosis. Dog. HE.

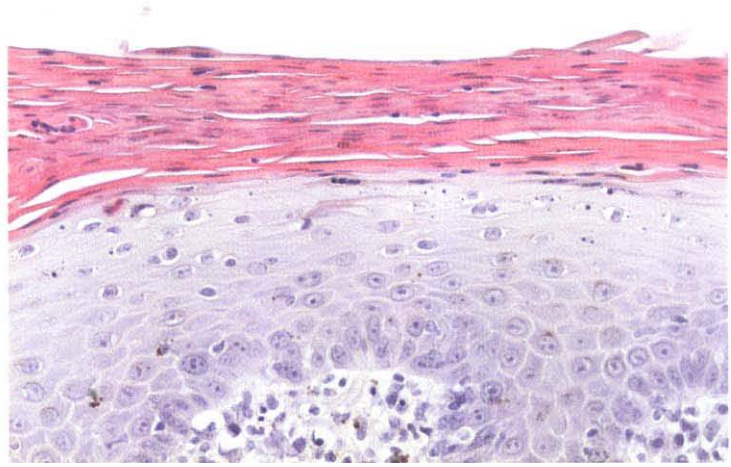
**13–5** Nodules
Several nodules in the dermis due to the proliferation of mesenchymal cells and deposition of mucins (glucosaminoglycans) in the intercellular matrix. Myxomatosis. Rabbit.

**13–6** Wheals
Well-circumscribed raised areas with a flat surface, caused by dermal edema, sometimes in combination with hyperemia. A condition in which many wheals are present is called urticaria or hives. Erysipelas. Swine.

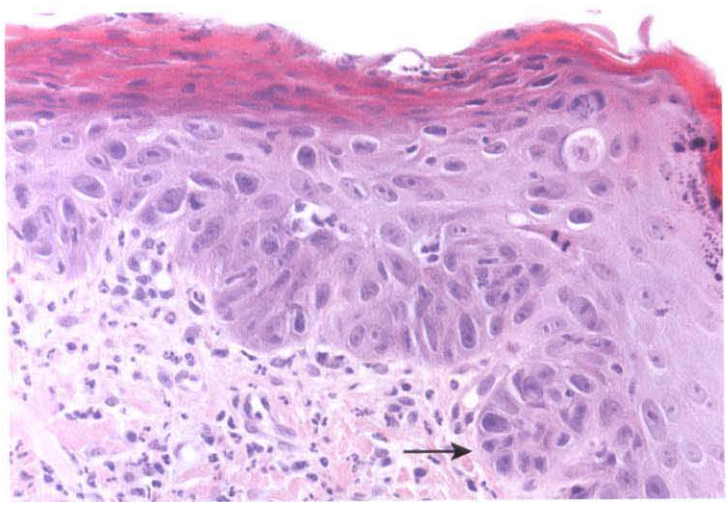
**13–7** Crusts
Dermatitis with distinct crusts composed of dried exudate, sebum, keratin and dirt: exudative epidermitis (generalized form). Greasy pig disease (*Staphylococcus hyicus*). Piglet, 3 weeks.

**13–8** Lichenification
Axillary area. Thickening of the skin with exaggerated superficial skin markings. Usually the epidermis as well as the dermis is hypertrophic. This secondary change can occur in cases of chronic dermatitis, as shown here. Dog.

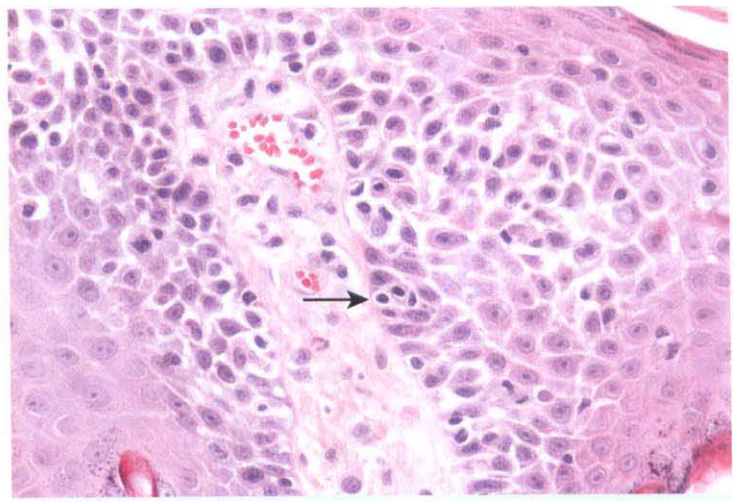
**13-9** Orthokeratotic hyperkeratosis
Increased thickness of the stratum corneum is referred to as orthokeratotic hyperkeratosis (often shortened to hyperkeratosis). There is a layer of anucleated keratin covering a hyperplastic epidermis with hyperplasia and hypertrophy of the basal cell layer and prominent nucleoli. Note large, pale keratinocytes (known as koilocytes) and large purple keratohyalin granules (arrow). Viral papilloma. Dog. HE.



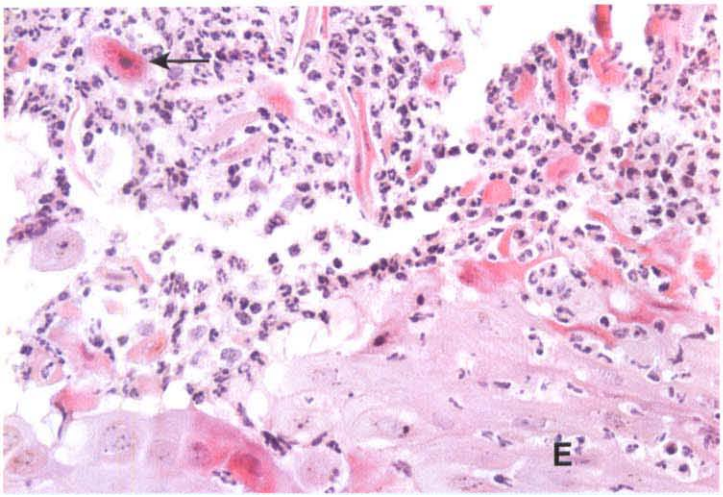
**13-10** Parakeratotic hyperkeratosis
Increased thickness of the stratum corneum with retention of keratinocyte nuclei is referred to as parakeratotic hyperkeratosis (usually shortened to parakeratosis). Note maintenance of nuclei in superficial cornified layer. Dog. HE.



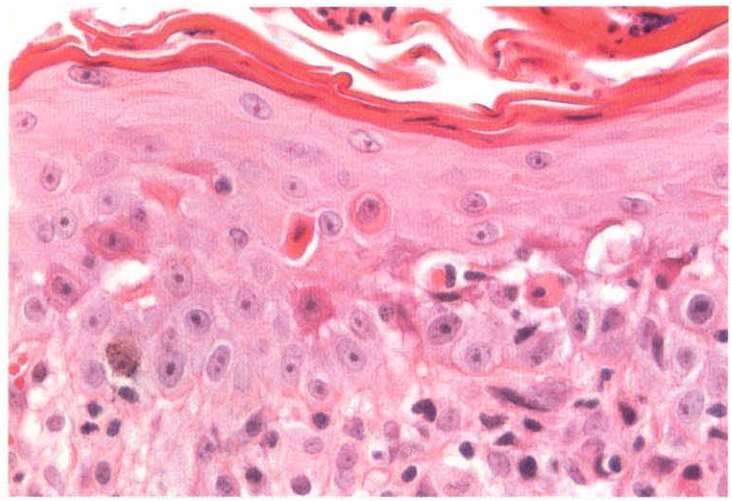
**13-11** Epidermal dysplasia
There is irregular epidermal hyperplasia with disorganized maturation of cells, anisokaryosis, hyperchromasia and prominent nucleoli. Note involvement of follicular epithelium (arrow). Dermal invasion is not present. Bowenoid *in situ* carcinoma. Cat. HE.



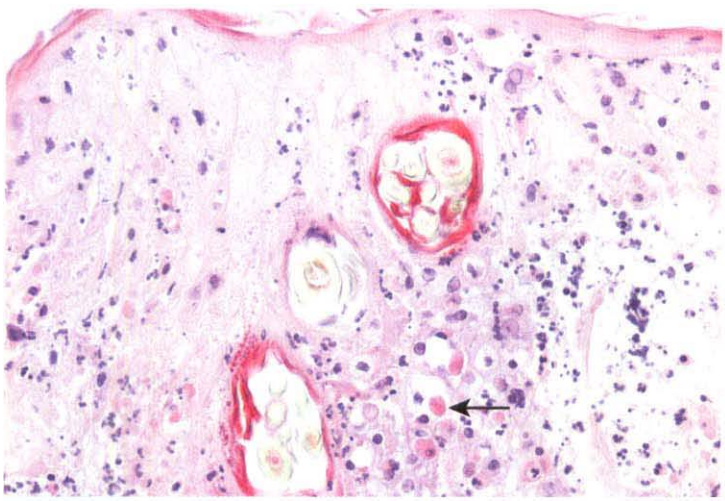
**13-12** Epidermal spongiosis
Spongiosis or epidermal edema is characterized by separation of keratinocytes by intercellular edema fluid; it may result in a vesicle. In this case there is also exocytosis of lymphocytes into the epidermis (arrow). Dog. HE.



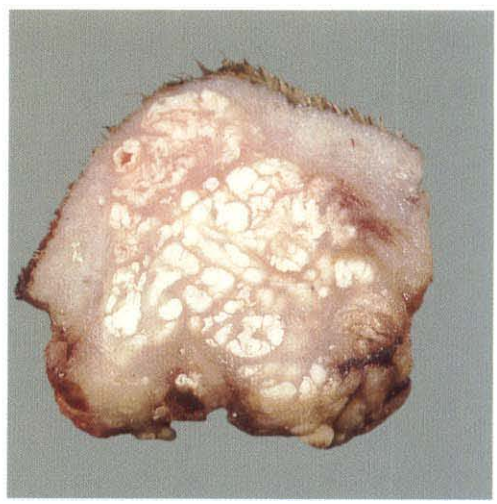

**13-13** Acantholysis
Pustule containing large numbers of neutrophils and acantholytic epidermal cells. Acantholytic cells have hypereosinophilic cytoplasm and generally contain normal nuclei (arrow). *Pemphigus foliaceus*. Dog. HE.



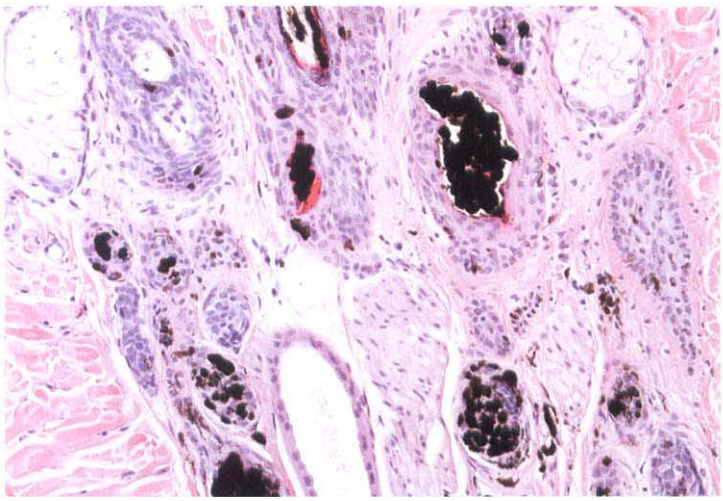
**13-14** Apoptosis
Several deeply eosinophilic, shrunken apoptotic cells with pyknotic nuclei in the basal and spinous layers of the epidermis. *Erythema multiforme*. Dog.



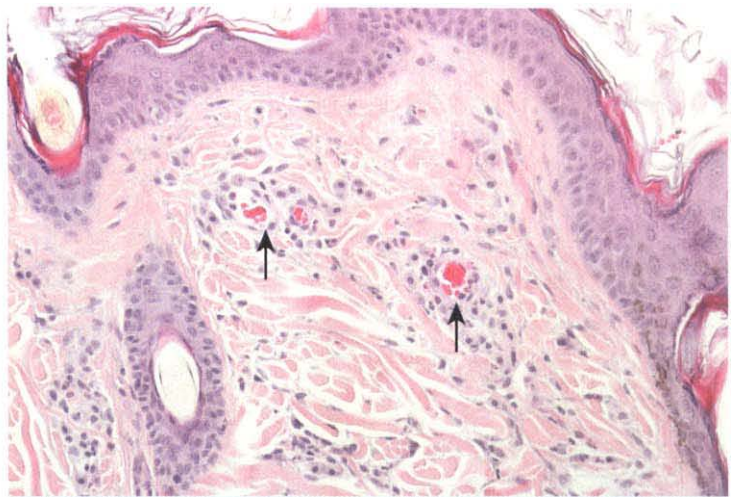
**13-15** Epidermal necrosis
Full-thickness necrosis of the epidermis and necrosis of follicular epithelium. Several intracytoplasmic viral inclusions within the cytoplasm of follicular epithelial cells are present (arrow). Cowpox virus infection. Cat. HE.



**13-16** Deposition of calcium salts
Nodule excised from the lateral aspect of the tarsus. White calcium deposits in dermis and subcutis, surrounded by gray fibrous tissue. Calcinogranuloma (*calcinosis circumscripta*). Dog.

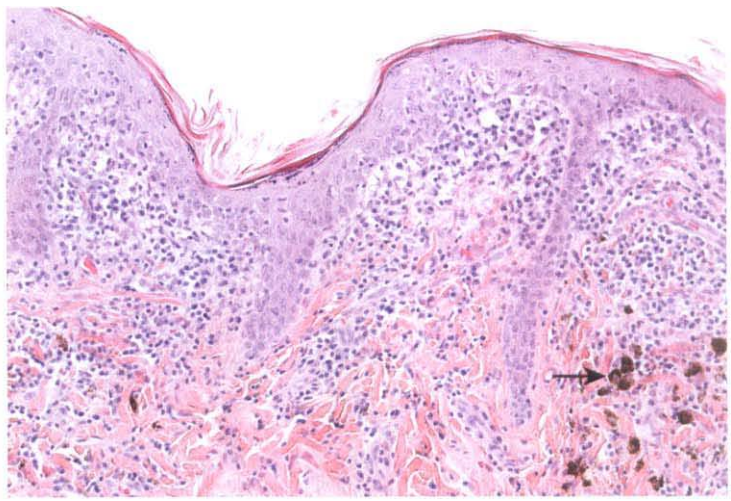


**13-17** Follicular dysplasia
Abnormal clumping of melanin in dysplastic hair follicles and in hair shafts. Color mutant alopecia. Doberman pinscher dog. HE.

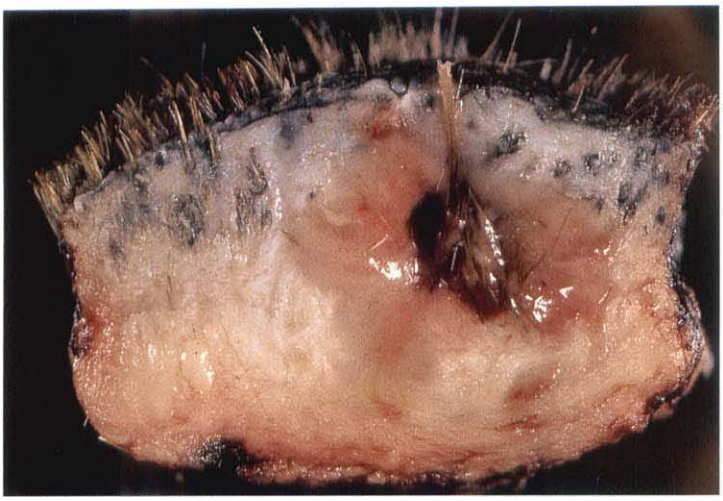


**13-18** Perivascular dermatitis
The superficial dermis reveals perivascular inflammation (arrows) with dilation of dermal capillary blood vessels. This reaction pattern is shared by many common skin diseases especially allergic dermatitis. Dog. HE.

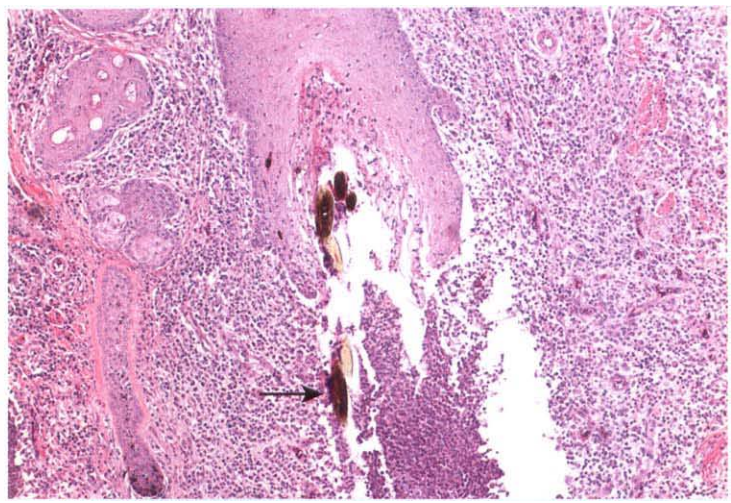
**13-19** Dermatitis
Dermatitis involving the perioral, periocular and nasal skin. Lesions at the mucocutaneous junctions often have an immune-mediated pathogenesis. Toxic epidermal necrolysis. Dog.



**13-20** Interface dermatitis
There is a moderate mixed superficial dermal inflammation partially obscuring the dermal-epidermal junction. Note pigmentary incontinence (arrow). Discoid *lupus erythematosus*. Dog. HE.

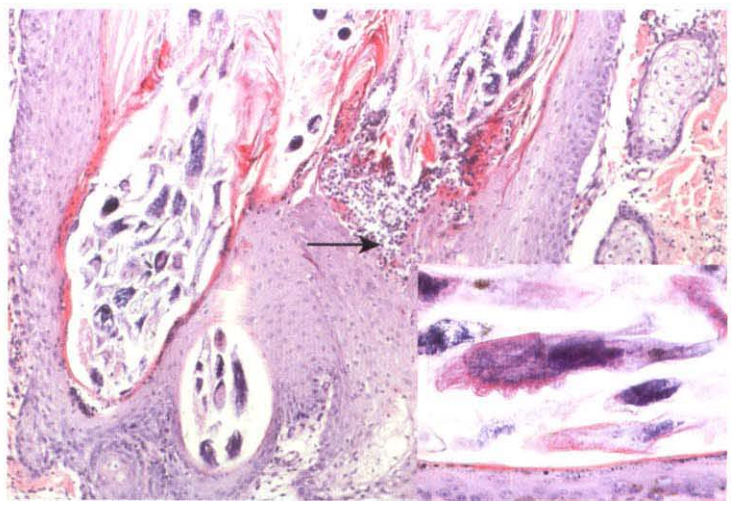


**13-21** Furuncle
Suppurative inflammation originating in a hair follicle and extending into the surrounding dermis. Dog.



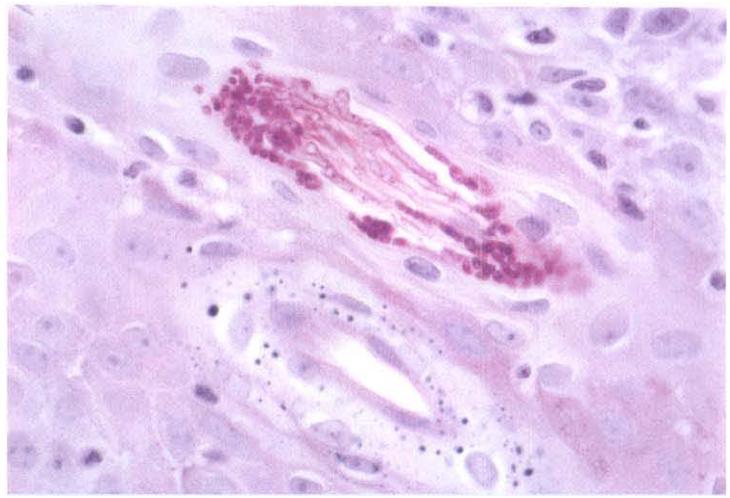
**13-22** Folliculitis and furunculosis
Luminal folliculitis (arrow) followed by rupture of follicular epithelium, release of hair shafts into dermis and severe perifollicular pyogranulomatous inflammation, typical of furunculosis. Dog. HE.

**13-23** Alopecia
Areas of alopecia on the head and neck. Demodicosis. Dog.



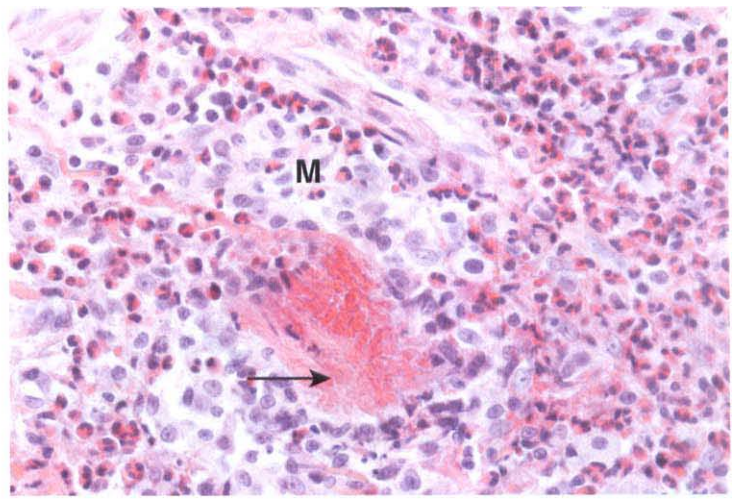
**13-24** Parasitic folliculitis
Luminal folliculitis (arrow) and perifolliculitis with numerous *Demodex* mites within follicular lumens. Inset: *Demodex* mite to illustrate whole mite; note legs. Demodicosis. Dog. HE.

**13-25** Dermatitis and crust formation
Circumscribed area with alopecia and crust formation. Dermatophytosis (syn. 'ringworm') caused by *Trichophyton* infection. Cow.

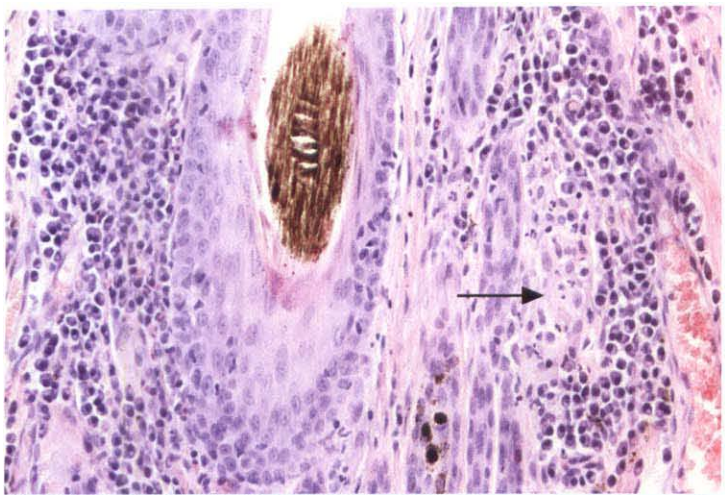


**13-26** Fungal infection
Hair shaft contains arthrospores and hyphae. In the dog, *Microsporum canis* is the most common cause of dermatophytosis. Dog. PAS stain.

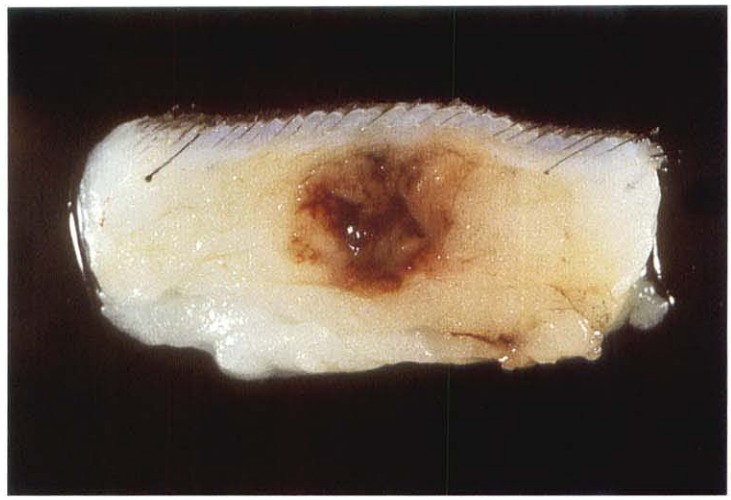
**13-27** Granulomatous dermatitis
Thickening of the upper lip. Histologically, there are three possible differential diagnoses for these lesions in the lips of cats: indolent ulcer, eosinophilic granuloma or eosinophilic plaque. Cat.



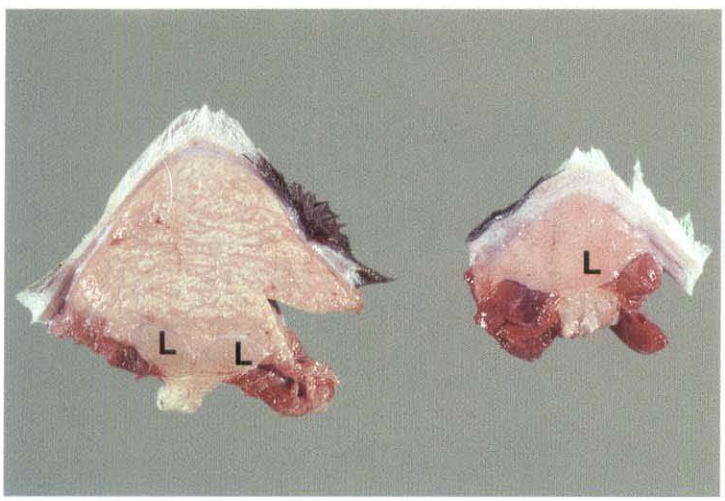

**13-28** Degranulation of eosinophils around collagen fibers in dermis
Brightly stained, eosinophilic, amorphous debris (degranulation of eosinophils) and collagen fibers; known as 'flame figure' (arrow). Surrounded by a layer of macrophages (M) and numerous intact eosinophils in the dermis. Eosinophilic granuloma. Cat. HE.



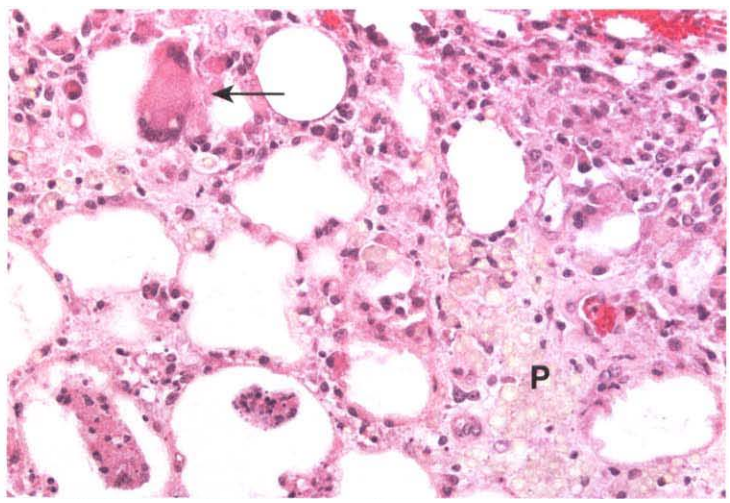
**13-29** Sebaceous adenitis
Periadnexal granulomatous inflammation at the site of previous sebaceous glands (arrow). Sebaceous adenitis. Dog. HE.



**13-30** Nodular panniculitis
The subcutis contains a circumscribed nodule of inflammation. Nodular panniculitis. Dog.

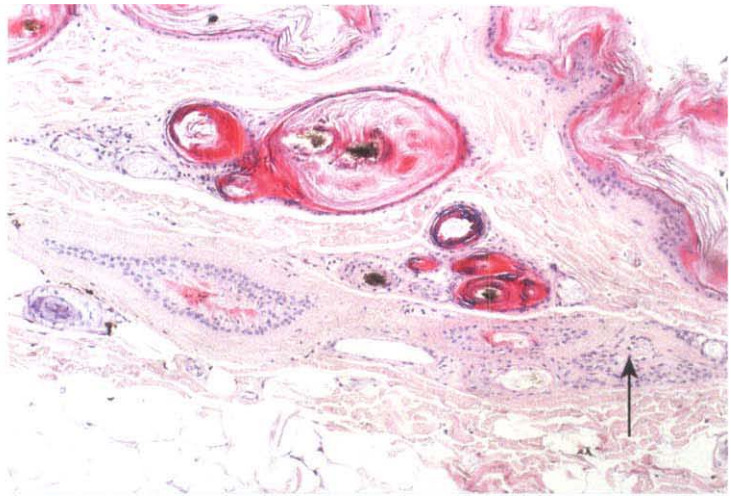



**13-31** Panniculitis/steatitis
Cross-section of fatty crest dorsal to the nuchal ligament (L) of two ponies. Swelling and multiple yellowish lobules of necrotic fat tissue (at left) in pony with nutritional steatitis ('yellow fat disease'). Fatty crest and nuchal ligament of normal pony at right.

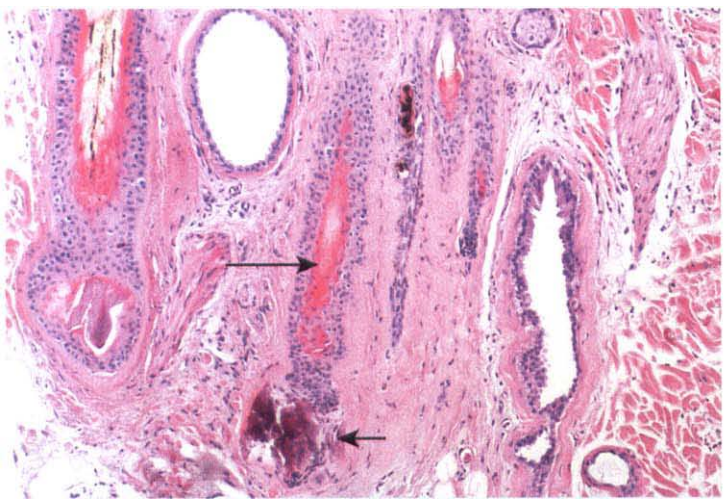



**13-32** Panniculitis/steatitis
Necrosis of fat tissue, chronic granulomatous inflammation with multinucleated giant cells (arrow) and macrophages containing yellowish pigment (P). Infiltration of inflammatory cells in and around ruptured adipocytes. Nutritional steatitis. Pony. HE.

**13-33** Alopecia
Bilaterally symmetric alopecia and a pendulous abdomen due to hypercortisolism (Cushing's syndrome). The alopecia is caused by atrophy of the hair matrix. This type of alopecia may also by caused by other hormonal imbalances. Dog.



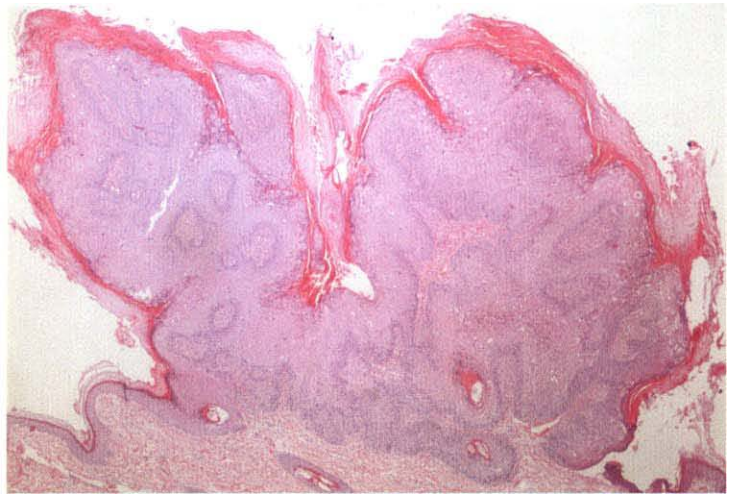
**13-34** Follicular and dermal atrophy with telogen hair follicles
The infundibula of hair follicles are filled with keratin plugs (follicular keratosis). The dermis is atrophic. In the lower part of the picture some atrophic (telogenic) hair matrices can be observed (arrow). Hypercortisolism (Cushing's disease). Dog. HE.



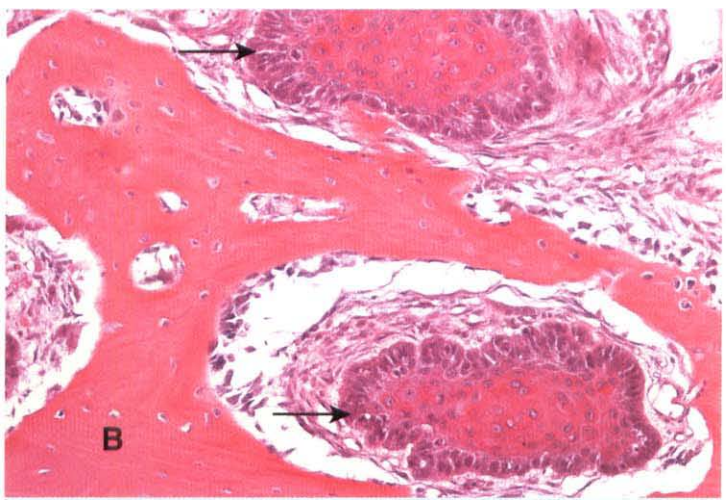
**13-35** Follicular atrophy with catagen hair follicles
Follicles in catagen stage with extensive tricholemmal keratinization also referred to as flame follicle (at left). Note atrophic hair bulb attached to outer root sheath (long arrow) and calcification of connective tissue (short arrow). Hypercortisolism (Cushing's disease). Dog. HE.

**13-36** Sweat gland cyst
Cystic space, filled with a clear fluid. Microscopic examination of the wall revealed an inner lining composed of cuboidal cells characteristic of apocrine sweat gland epithelium. Dog.

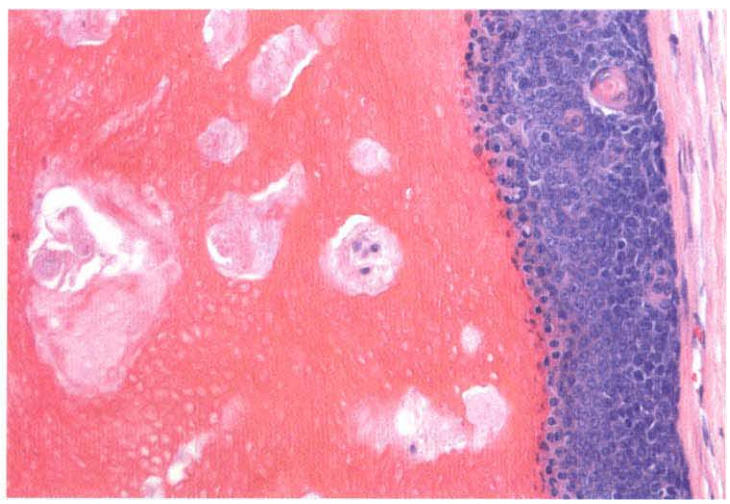
**13-37** Papilloma
Benign papilliferous tumor of the epidermis. Cow.



**13-38** Papilloma
Exophytic papilloma with papillary projections covered by hyperplastic, hyperkeratotic epithelium. Viral papilloma. Dog. HE.

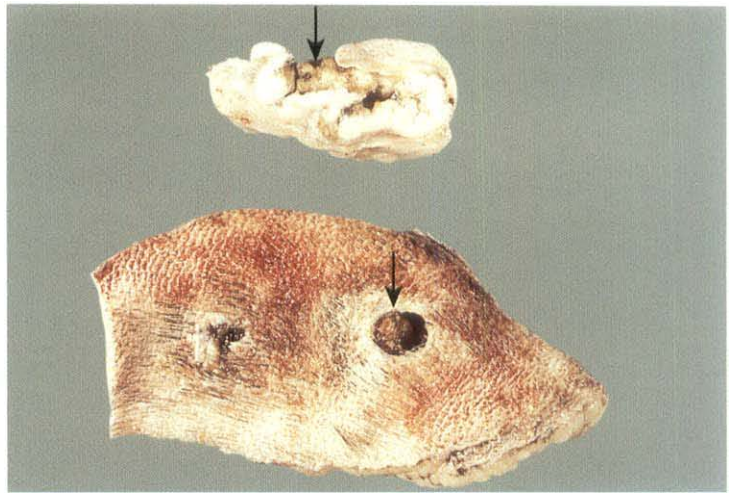



**13-39** Squamous cell carcinoma
Squamous cell carcinoma (arrows) infiltrating into the phalangeal bone (B). Nailbed squamous cell carcinoma. Dog. HE.

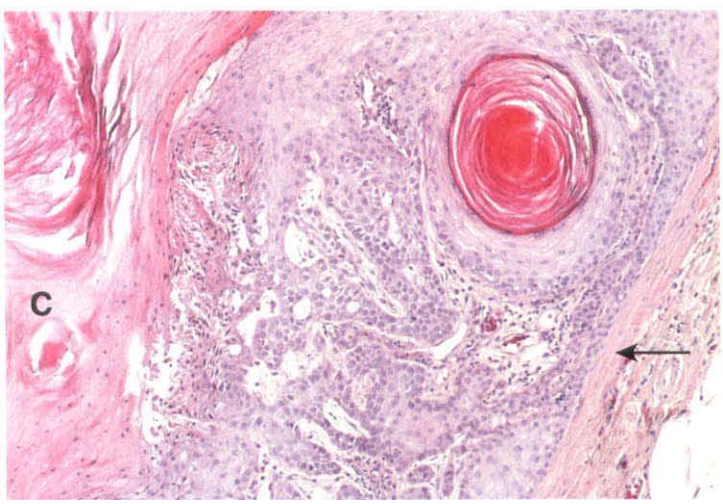


**13-40** Follicular cyst
In this follicular cyst of the matrical type the wall is composed of basaloid epithelial cells. There is abrupt keratinization and the cyst cavity contains keratin in which numerous pale nuclear outlines ('ghost cells') are present. The structure of the wall in matrical cyst is similar to the walls lining cystic structures in pilomatricoma (see Fig. 13-41). Most follicular cysts (of the infundibular type) are lined by a layer of squamous epithelium. Dog. HE.

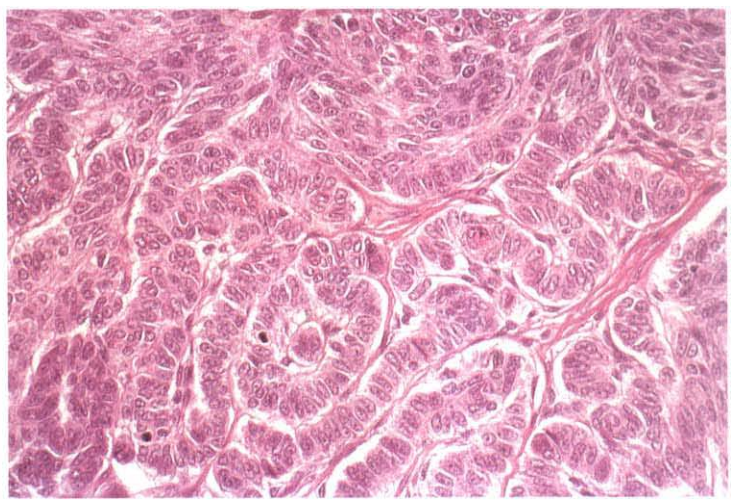
**13-41** Pilomatricoma
Macroscopic view of a calcified pilomatricoma (syn. necrotizing and calcifying epithelioma of Malherbe) in the dermis and subcutis. Dog.



**13-42** Infundibular keratinizing acanthoma
This tumor (syn. keratoacanthoma or intracutaneous cornifying epithelioma) presents as solitary or multiple nodule(s) and usually has an opening to the skin surface through a pore; this can be seen on the surface and in the cross-section at the upper part of the photograph (arrows). Dog.

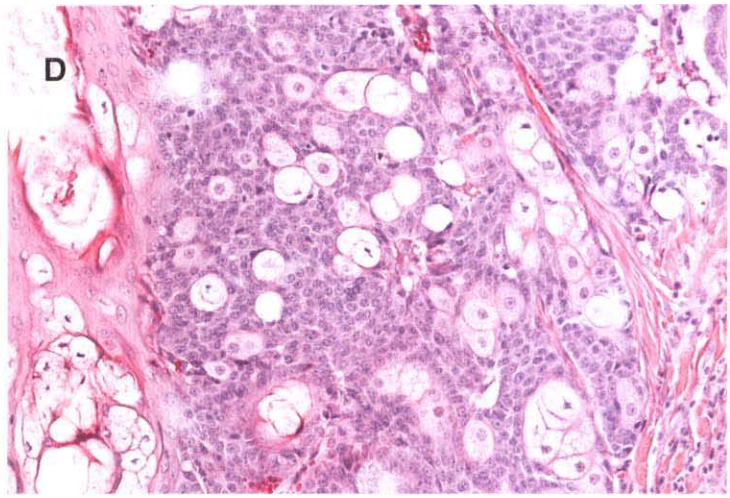



**13-43** Infundibular keratinizing acanthoma
A keratin-filled cystic structure (C) is lined by a wall composed of horn cysts and cords and trabeculae of epithelial cells. The tumor in the dermis is well-encapsulated (arrow). Dog. HE.

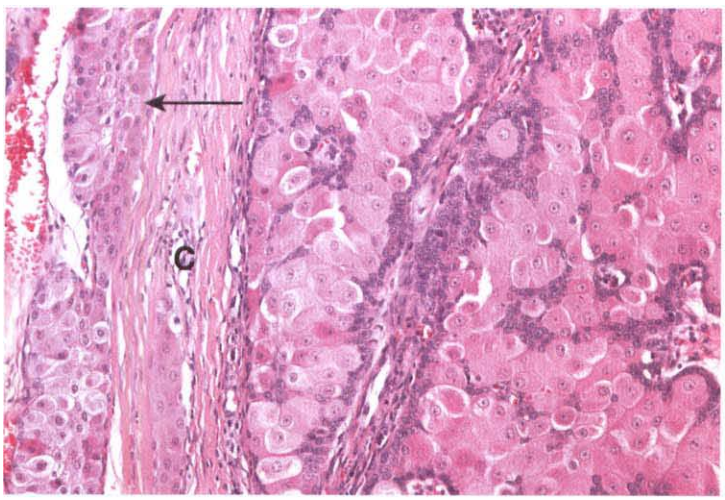


**13-44** Trichoblastoma
Ribbon type trichoblastoma consisting of epithelial cells arranged in columns with their nuclei orientated perpendicular to the long axis of the columns. Dog. HE.

**13-45** Sebaceous gland hyperplasia
Small wart-like tumors on the ear. Dog.

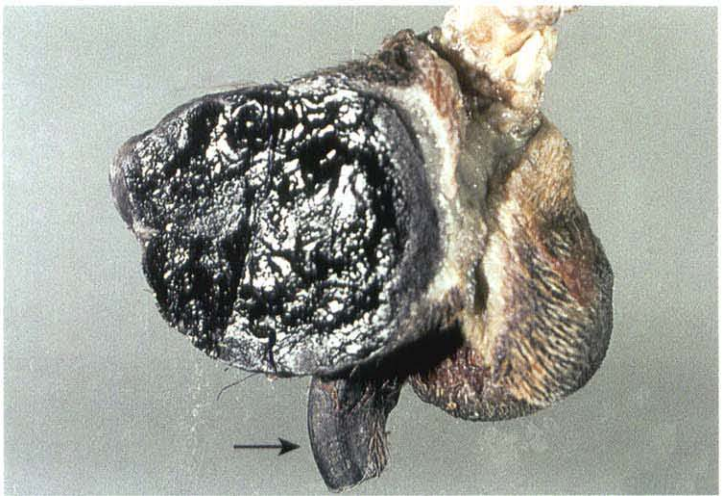



**13-46** Sebaceous gland adenoma
Lobules of reserve cells and multiple clusters of sebaceous cells. Some ducts at left (D). Dog. HE.

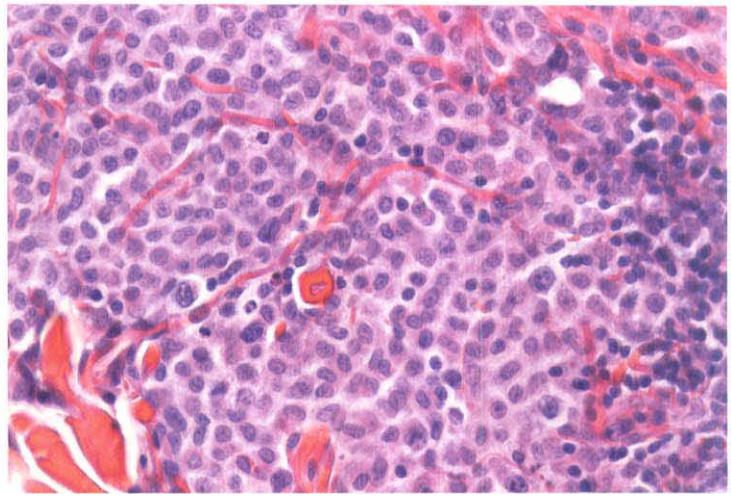



**13-47** Perianal gland adenoma
The tumor is encapsulated (C) and composed of lobules of large polygonal cells (hepatoid aspect) with small reserve cells at the periphery. Lobules of normal hepatoid glands at left (arrow). Dog. HE.

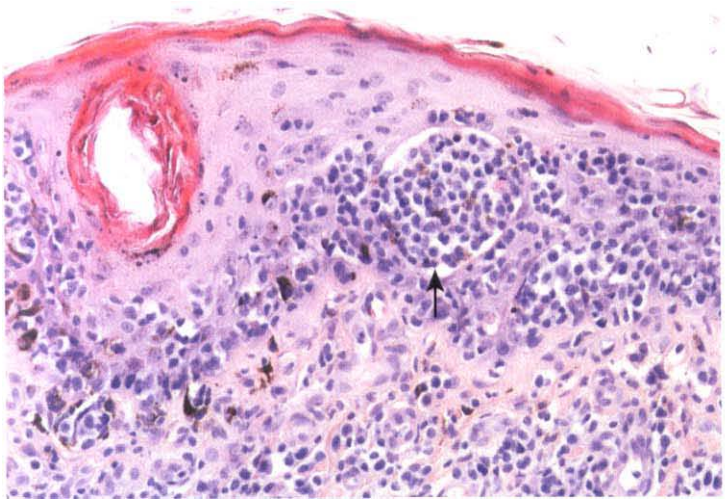
**13-48** Equine sarcoid
Dermal spindle-cell tumor extending to the dermal–epidermal junction. Long epidermal rete pegs (probably remnants of hair follicles) are characteristic. Horse. HE.



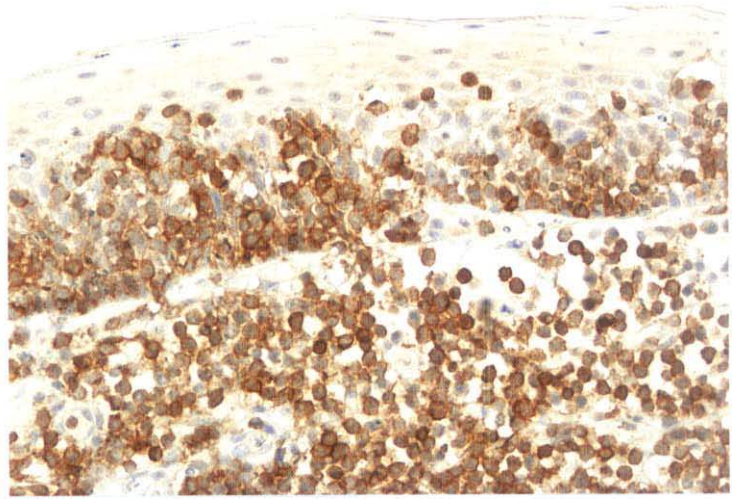
**13-49** Melanoma (malignant)
Digit with nail (arrow). Black tumor, consisting of heavily pigmented melanocytes. Dog.



**13-50** Canine histiocytoma
Intradermal round cell tumor with tumor cells arranged in sheets and groups. The tumor cells are Langerhans cells. Lymphocytic infiltration at right. Dog. HE.



**13-51** Epitheliotropic lymphoma
The epidermis and superficial dermis are infiltrated by neoplastic lymphocytes. The intraepithelial cells form a discrete aggregate referred to as Pautrier's microabscess (arrow). Dog. HE.



**13-52** Epitheliotropic lymphoma
Immunohistochemical staining of a skin section of a dog with epitheliotropic lymphoma using an antibody raised to CD3. Note abundant positive staining of neoplastic lymphocytes in the epidermis and dermis indicating T-cell lymphoma. Dog.

# Chapter 14
# The mammary gland



## THE MAMMARY GLAND

The most common pathological processes of the mammary gland are *inflammation* (mastitis) in farm animals and *neoplasia* in dogs and cats.

### *Inflammatory lesions*

Inflammatory lesions are classified according to their distribution and the nature of the inflammatory reaction.

#### Parenchymatous mastitis

*Parenchymatous mastitis* refers to inflammation of the secretory portion of the gland (acini, intralobular ducts and interstitium). In severe cases there may be extensive necrosis (referred to as gangrenous mastitis). After demarcation the necrotic part may be shed.

#### Galactophoritis

*Galactophoritis* refers to inflammation of the larger (interlobular) draining ducts.

#### Interstitial mastitis

*Interstitial mastitis* refers to inflammation of the stromal tissue.

#### Abscess formation

Suppurative inflammation may lead to *abscess formation*.

#### Granulomatous inflammation

*Granulomatous inflammation* is usually characterized by the presence of nodular lesions.

### *Neoplasms*

#### Dogs

In the dog various types of neoplasms occur with regard to structure as well as biological behavior. The morphological classification of canine mammary tumors depends on several characteristics including the way of growth and the cell type involved, i.e. luminal epithelial cells and/or myoepithelial cells and/or mesenchymal cells.

***Simple tumors***

In *simple mammary tumors* one cell type either resembling epithelial cells or myoepithelial cells, is involved.

***Complex tumors***

In *complex tumors* both luminal epithelial and myoepithelial components are present.

***Mixed tumors***

*Mixed tumors* are characterized by an epithelial component (luminal and/or myoepithelial) and mesenchymal cells that have produced cartilage and/or bone and/or fat.

***Inflammatory carcinoma***

A highly malignant type is the anaplastic carcinoma that, due to extensive infiltration and obstruction of lymphatics, has some clinical aspects of inflammation and is therefore referred to as inflammatory carcinoma or '*mastitis carcinomatosa*'.

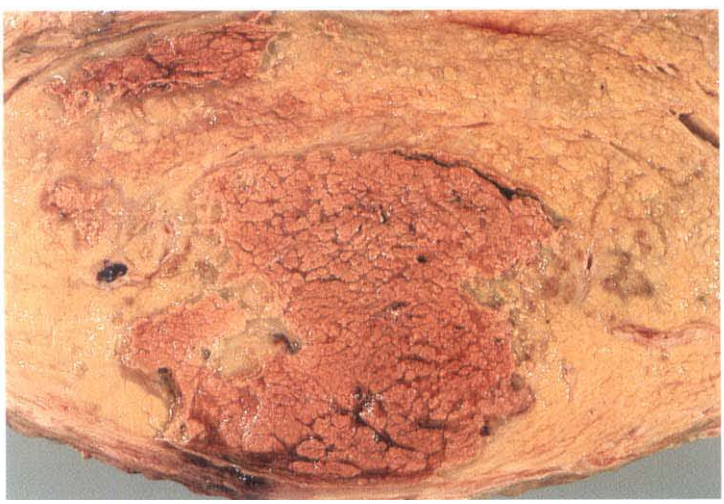
#### Cats

In cats, mammary tumors are mostly malignant and are predominantly tubular or solid adenocarcinomas.

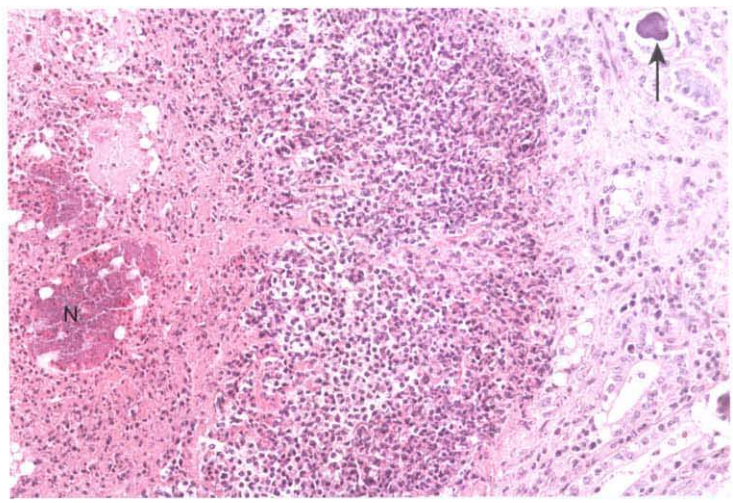
A common non-neoplastic lesion in the cat is the *fibroadenomatous change* or *fibroepithelial hyperplasia* associated with increased exposure to endogenous or exogenous progestogens.

**14-1** Acute mastitis
In the inflamed quarter there is a distinct hyperemia, which is absent in the normal quarter. The inflammation was caused by *Escherichia coli* and streptococci. Cow.

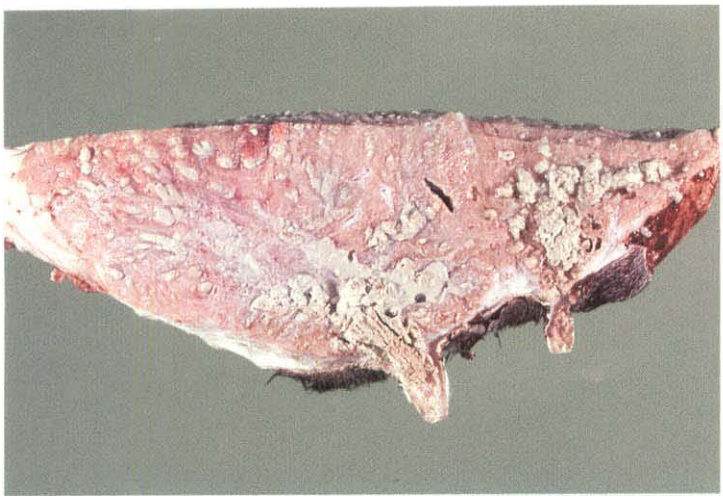
**14-2** Acute necrotizing mastitis
Dark blue discoloration of the skin of a swollen hindquarter, caused by a severe necrotizing inflammatory process, which is surrounded by a small hyperemic demarcation zone. The mastitis followed teat injury and was caused by *Escherichia coli* and *Clostridium perfringens*. Cow.



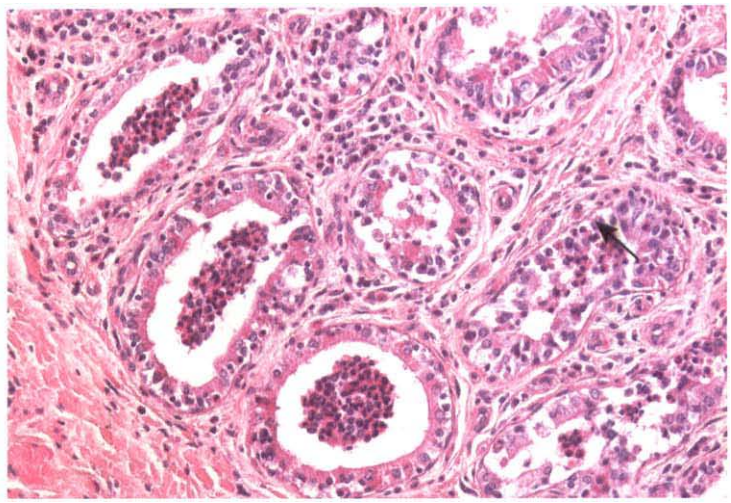
**14-3** Subacute necrotizing mastitis
One extensive area and a few smaller areas, with coagulation necrosis of mammary tissue in which the lobular pattern is still visible. Some grayish granulation tissue can be seen around the necrosis. *Escherichia coli* mastitis. Cow.



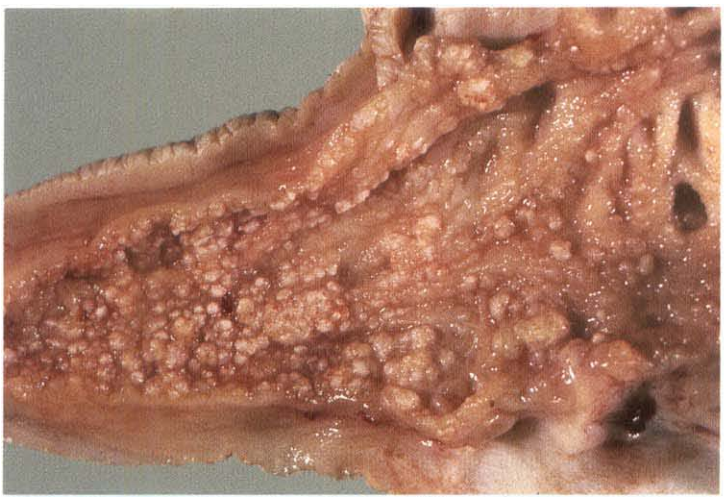

**14-4** Acute necrotizing mastitis
Focus of necrosis containing bacterial colonies (N) surrounded by a demarcation zone of intact and necrotic neutrophils. Mildly inflamed mammary gland tissue at right. Note corpus amylaceum (arrow). Cow. HE.



**14–5** Chronic purulent galactophoritis and mastitis
The cisterns and ducts are filled with purulent exudate. Fibrosis has developed in the periductular and glandular part of the udder. This pattern is mainly seen in streptococcal and staphylococcal infections. Cow.

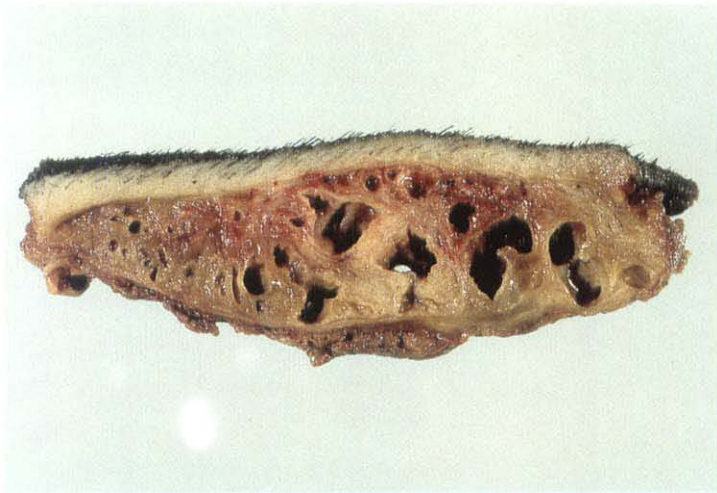


**14–6** Subacute mastitis
Acini contain inflammatory cells predominantly neutrophils. In some acini destruction of epithelial cells is seen (arrow). There is an increase in interstitial connective tissue that contains mononuclear cells especially lymphocytes and plasma cells. Cow. HE.



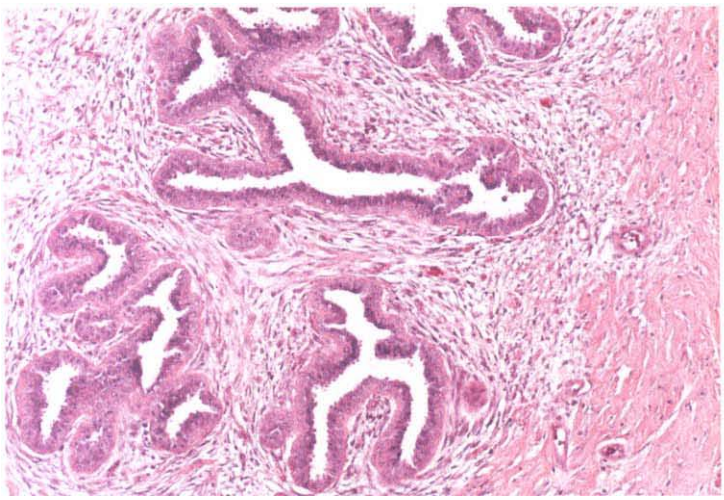
**14–7** Metaplasia of cisternal epithelium
Opened teat. There is metaplasia of cisternal epithelium, which has changed into cornifying stratified squamous epithelium. The change is most obvious in the teat cistern giving the surface a granular aspect. It is most commonly seen as a consequence of chronic galactophoritis. Cow.

**14–8** Granulomatous mastitis
Cut surface. The udder contains numerous yellowish-brown, often coalescing nodules caused by granulomatous inflammation. Mastitis due to *Staphylococcus* sp. Cow.



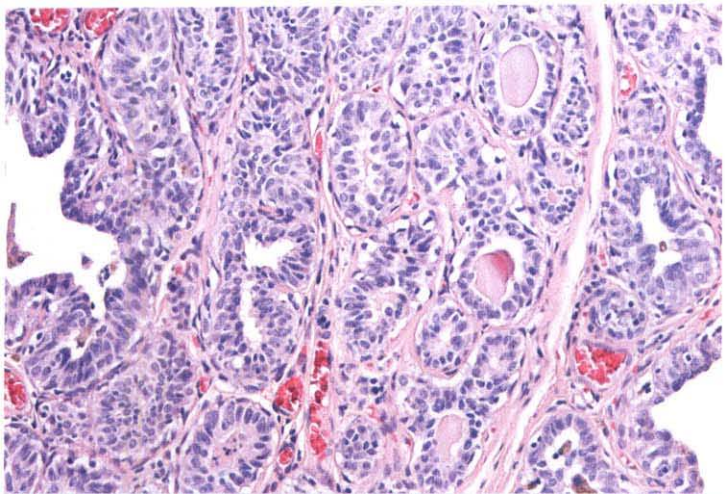
**14–9** Duct ectasia
Excision from a mammary gland of a dog. There are several irregular cavities within the mammary gland. On histology marked ectasia of mammary gland ducts were present. Dog.

**14–10** Fibroadenomatous change (fibroepithelial hyperplasia)
Multiple firm, large, well-circumscribed nodules in the mammary glands. Cat.

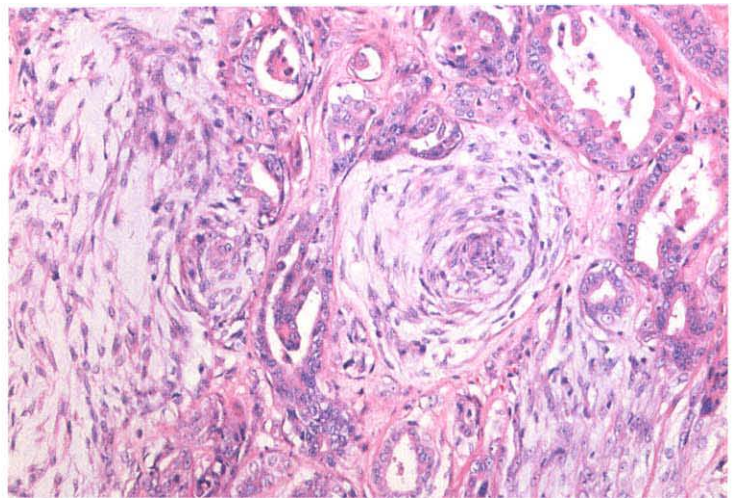


**14–11** Fibroadenomatous change (fibroepithelial hyperplasia)
Mammary gland. Proliferation of intralobular ducts surrounded by edematous fibrous stroma. Cat. HE.

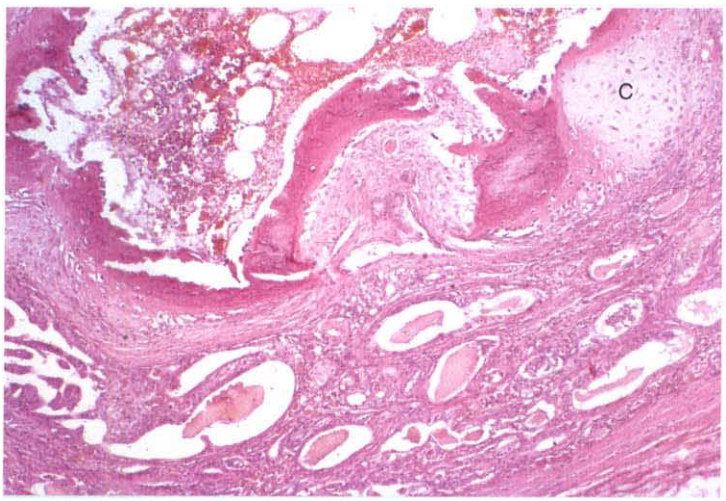
**14–12** Mammary gland carcinoma
Ulcerated tumor in the thoracic region of a bitch. Dog.



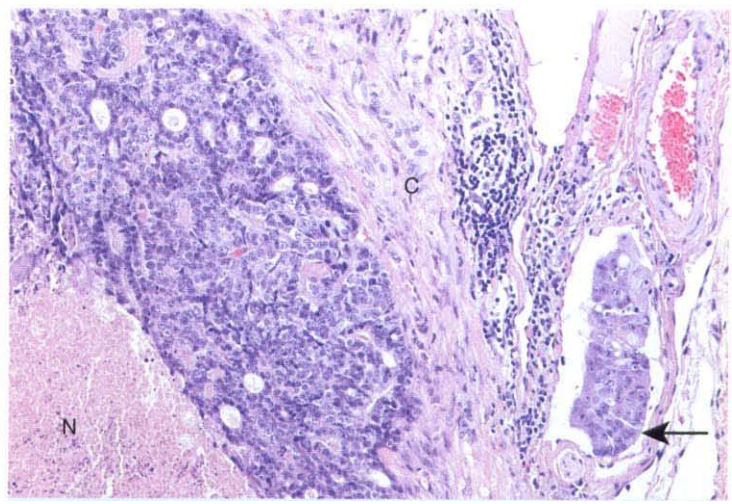
**14–13** Simple adenoma
Skin on mammary gland. Neoplasm is composed of tubules lined by a single layer of epithelial cells. There is scant fibrous stroma. Bitch. Dog. HE.



**14–14** Complex adenoma
Mammary gland. Portion of a tumor lobule composed of tubular structures lined by epithelial cells and myxoid tissue containing proliferating myoepithelial cells. Bitch. Dog. HE.




**14–15** Benign mixed tumor
Mammary gland. The lower part of the photomicrograph shows the epithelial part of the tumor. Other elements, such as cartilage (C) and bone including marrow-like structures (upper left), are visible. (Tissue not demineralized). Bitch. Dog. HE.




**14–16** Adenocarcinoma
Mammary gland. Tumor lobule comprising numerous small tubules (at left) surrounded by fibrous connective tissue (desmoplasia; C). There is a tumor embolus within a lymph vessel (arrow). Also note necrosis within tumor (N). Cat. HE.

Chapter 15

# The eye



## THE EYE

The eye is made up of several highly specialized tissues and structures all contained in an enclosed environment in order to facilitate the registration of visual stimuli.

### *Effects of reactivity on function*

General reaction patterns of ocular tissues are comparable to those in other parts of the body. However, because of the very strict tissue-specifications, ocular reactions may have more severe or even disastrous consequences with regard to the function of the affected structures, and consequently also to the function of the eye.

For instance, edema results in loss of translucency of the cornea or causes retinal detachment and has grave consequences for vision.

Wound healing in the cornea is similar to wound healing in the skin. Nevertheless, formation of granulation tissue will lead to loss of transparency of the corneal stroma and loss of function.

### *Developmental defects*

The embryological formation of the eye is an intricate interaction between different germinal layers, which results in the formation of the highly differentiated tissues, optimally equipped for their respective functions (light transmission through cornea, aqueous, lens and vitreous, and light registration in the retina). Developmental defects are common in domestic animals, especially in the dog, and can lead to different, sometimes complex morphological abnormalities with a varying degree of loss of function.

Abnormal formation of the lens vesicle will lead to abnormal induction of several other ocular structures and subsequent *microphthalmia*.

Abnormal retinal development is histologically characterized by the formation of rosettes as occurs in animals with *hereditary retinal dysplasia*, or as a consequence of viral infections during pregnancy.

### *Inflammation*

The nomenclature of inflammation in the globe is related to the structure affected. Inflammation frequently originates from the uveal tract and is called *(pan)uveitis*. Uveitis is a frequent component of most intraocular diseases due to the high vascularity of the uveal tract. The uvea is a contiguous structure but the individual constituents of the uveal tract (iris, ciliary body, choroid) may be inflamed separately (*iritis, cyclitis, choroiditis*).

Inflammation involving all tunics of the eye is called a *panophthalmitis*.

### *Glaucoma*

*Glaucoma*, increased intraocular pressure, is subdivided in open-angle and closed-angle glaucoma, or in primary and secondary glaucoma.

#### Primary glaucoma

Primary glaucoma is usually defined as idiopathic, as the cause is mostly unknown.

In several canine breeds a hereditary, primary, open drainage-angle glaucoma can develop due to abnormal formation of the pectinate ligament and trabecular meshwork, also known as *goniodysgenesis*.

#### Secondary glaucoma

Secondary glaucoma is associated with an underlying intraocular pathology (e.g. inflammation, lens luxation).

## Cataract

The lens is completely of epithelial origin, surrounded by a thick basement membrane (the lens capsule) and is translucent by virtue of its crystalline composition and lack of pigment and blood vessels. Because of this lack of vascularization, an inflammatory reaction from within the lens is impossible.

Reduced transparency of the lens is called *cataract* and has different causes (e.g. intraocular inflammation, trauma, toxins). Histologically, cataract is characterized by a limited set of lesions. Morphological changes can affect:

- the capsule (e.g. thickening, thinning, rupture);
- the epithelium (e.g. degeneration, necrosis, proliferation); and
- the lens fibres (e.g. degeneration, sclerosis).

Distinctive histological lesions in the cataract lens comprise *bladder cells* (large swollen epithelial cells) and *Morgagnian globules* (fragmented and disintegrated lens fibers).

## Retinal atrophy

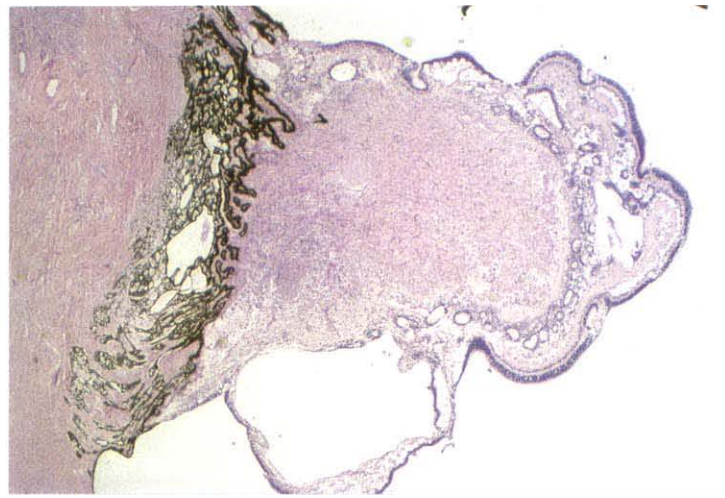
The retina is derived from the neurectodermal germinal layer and contains photoreceptor cells. The retina is typically composed of ten different layers and communicates with the brain through the optical tract that enters the retina in the optical papilla.

*Atrophy* is a general response of the retina and can be the consequence of glaucoma, but is also known as a progressive hereditary trait in some canine breeds.

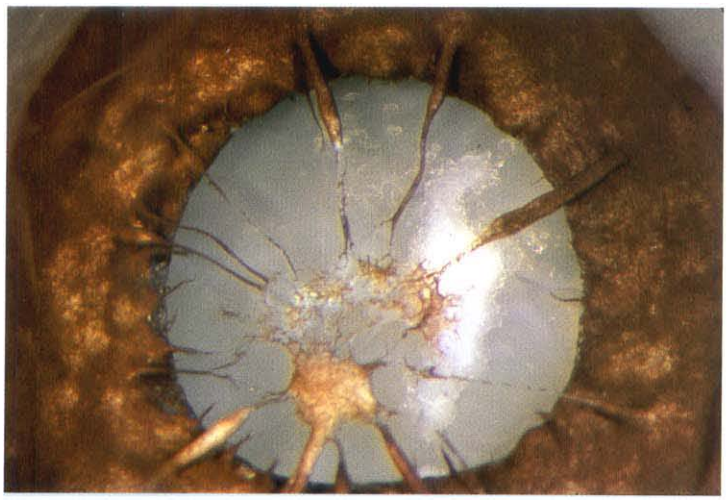
## Neoplasia

*Neoplasms* in the globe are relatively common in companion animals. They may be primary ocular (e.g. iris melanoma, iridociliar adenoma), metastatic or associated with periocular tissues like the eyelids. Post-traumatic sarcomas are a well-known phenomenon in cats.

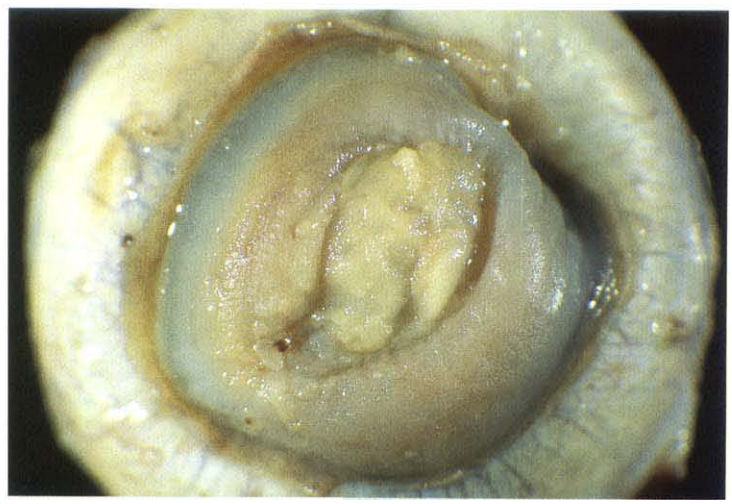
**15-1** Microphthalmia
Enucleated eye, sagittal section. Small, normal-shaped eye with pigmented cornea. No recognizable anterior chamber, ciliar apparatus or lens. A white conical structure with a black rim and black spots is attached to the optical papilla. Texel sheep.



**15-2** Microphthalmia
Microscopic aspect of the conical structure (see Fig 15-1) consisting of stromal tissue and a cystic structure, and covered with partly dysplastic retinal tissue. Texel sheep. HE.



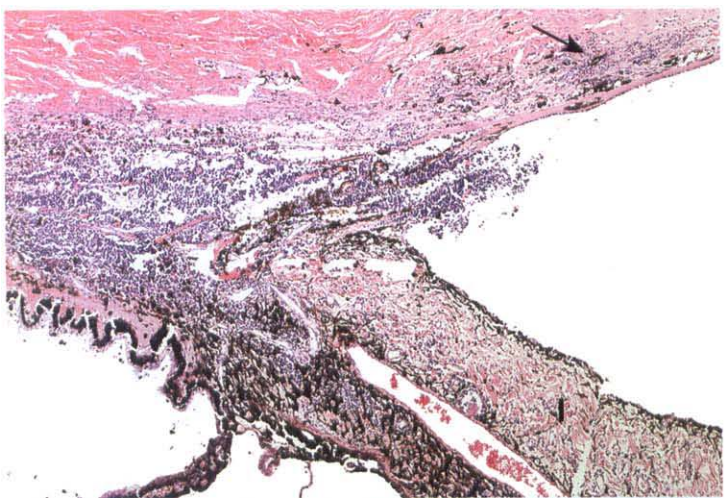
**15-3** Persistent pupillary membrane
Enucleated eye, cornea removed. Frontal view of the iris and lens. Strands of pigmented fibrous tissue, which are remnants of the anterior tunica vasculosa lentis, running from the iris to the lens. Focal anterior cataract (white areas). Golden retriever dog.



**15-4** Corneal ulceration
Enucleated eye. Frontal view of the cornea and sclera. Central necrosis and inflammation of the cornea with ulceration. Dog.

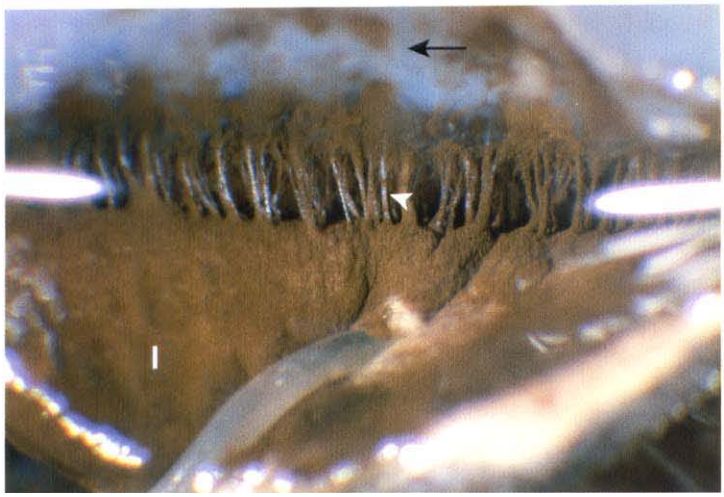
**15-5** Corneal rupture with scar tissue and retrocorneal fibrovascular membrane
Cornea with a ruptured, curled Descemet's membrane (arrow). In the course of wound healing, scar tissue in the corneal stroma (asterisk) and a retrocorneal fibrovascular membrane (arrowhead) have been formed. Dog, HE.

**15-6** Hypopyon
Accumulation of purulent exudate in the anterior eye chamber due to a suppurative uveitis. *Escherichia coli* infection. Foal.

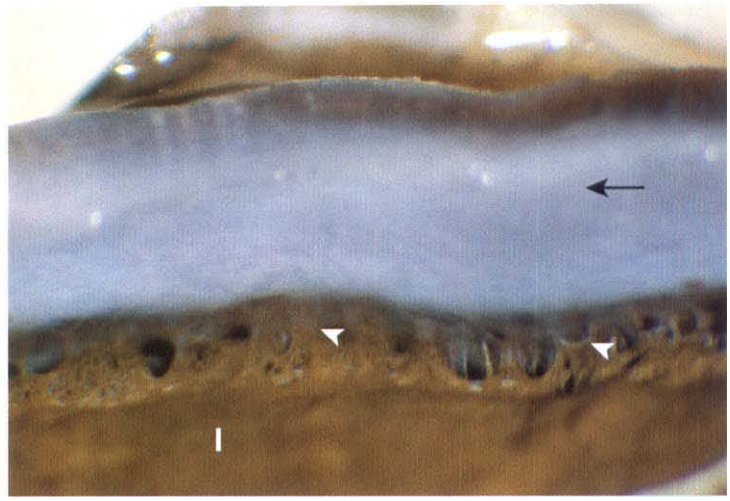


**15-7** Iridocyclitis
Infiltration of trabecular meshwork, iris (I), ciliary body and cornea (arrow) by mononuclear inflammatory cells (mainly plasma cells). Dog. HE.

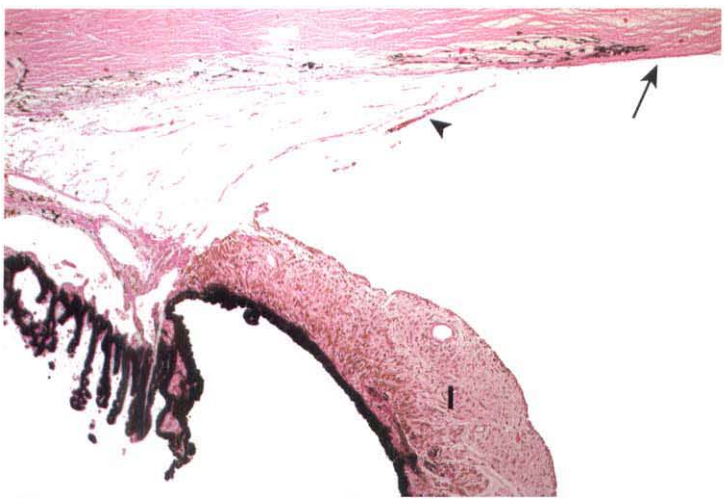
**15-8** Glaucoma
Enlarged left eye with severe edema of the cornea (the cornea appears opaque). Blockage of the drainage angle by accumulation of exudate, resulting in an increased intraocular pressure (secondary glaucoma), and in this case enlargement of the eye (buphthalmus). Iritis. Cat.



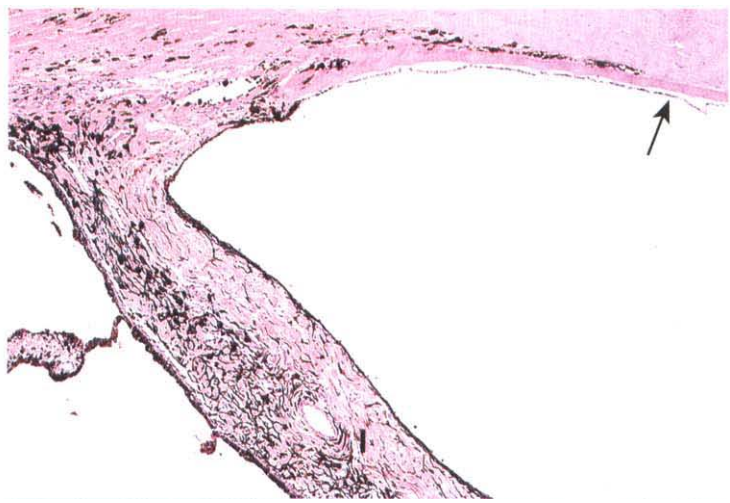
**15–9** Normal pectinate ligament
Enucleated eye, sagittal section. Stereomicroscopical view of the drainage angle between the cornea (arrow) and iris (I) revealing fine filaments (arrowhead) of the pectinate ligament. This normal arrangement of the filaments allows unobstructed outflow of aqueous into the trabecular meshwork. Bouvier des Flandres dog.



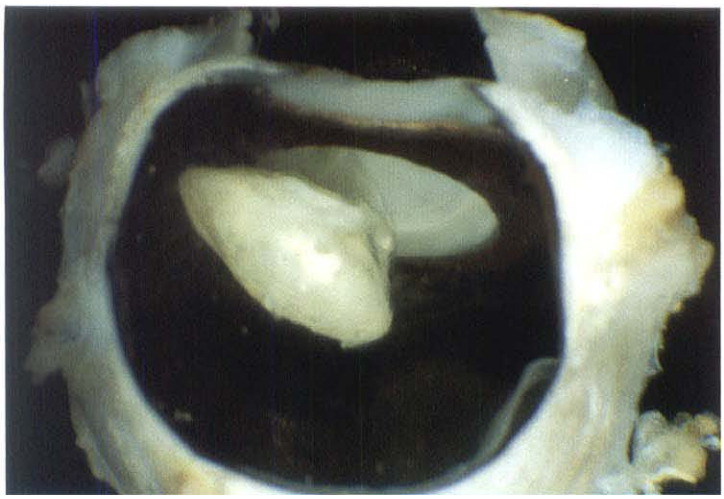
**15–10** Dysplastic pectinate ligament
Enucleated eye, sagittal section. Stereomicroscopical view of the drainage angle between the cornea (arrow) and iris (I). Note the abnormally shaped (shortened, thickened and fused) trabecula of the pectinate ligament (arrowheads). Dysplasia may lead to obstruction of the aqeous and a subsequent rise in intraocular pressure (glaucoma). Bouvier des Flandres dog.



**15–11** Normal drainage angle
Normal drainage angle between the cornea (arrow) and base of the iris (I) with a portion of the pectinate ligament (arrowhead). Note the very loose aspect of the trabecular meshwork (upper left). Dog. HE.

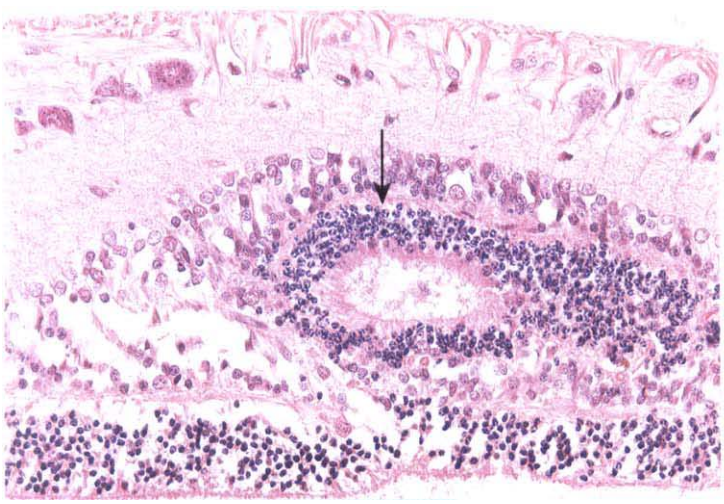


**15–12** Goniodysgenesis
Open drainage angle between the cornea (arrow) and iris (I), but complete collapse of the trabecular meshwork. A distinctive pectinate ligament is not distinguishable. Dog. HE.

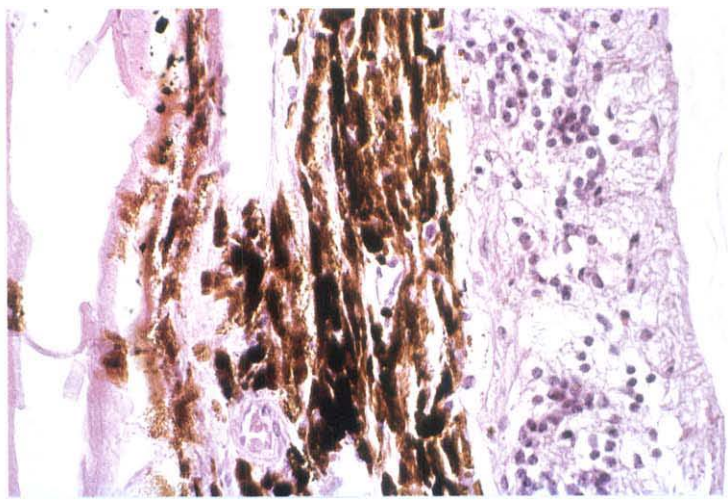


**15-13** Luxation of the lens
Enucleated eye, sagittal section. Luxation of the lens in the vitreous body. Cataractous lens (mature cataract). Dog.

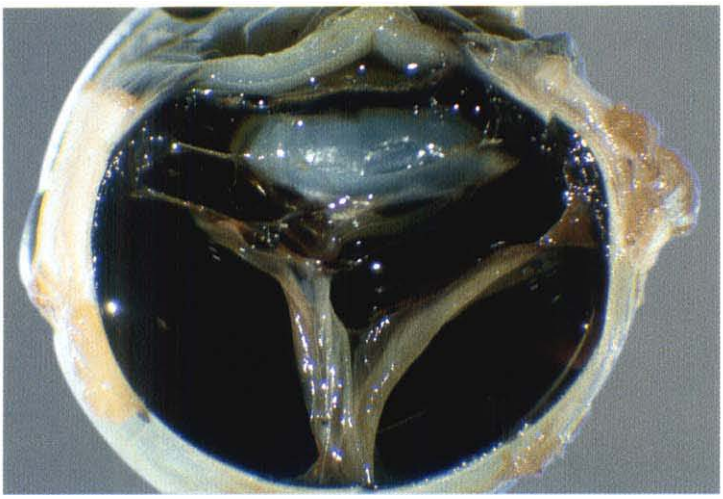
**15-14** Cataract
Severe swelling of lens epithelium (bladder cells; arrow) and spherical remnants of the lens matrix (Morgagnian globules; arrowhead). Note the normal capsule (asterisk). Dog. HE.



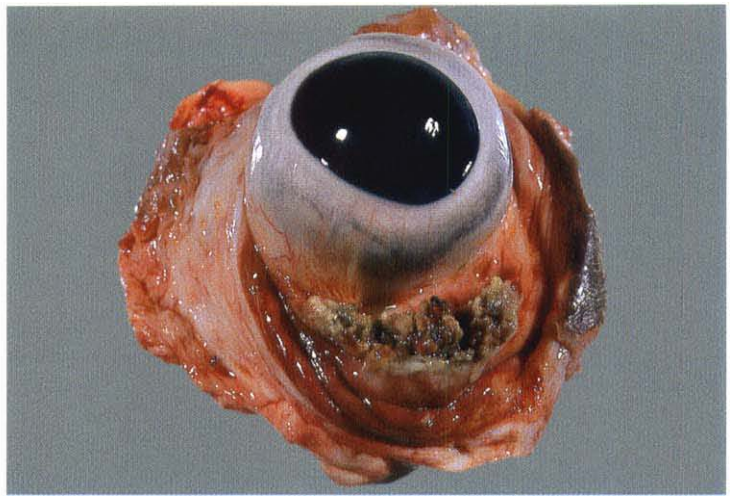
**15-15** Retinal dysplasia
Rosettes (arrow) are typical morphological lesions in a dysplastic retina. The rosette consists of layers of differentiated neural cells surrounding a central lumen. This eye also had retinal detachment with a typical 'tomb-stone' appearance of the retinal pigment epithelium (not visible in this picture). Dog. HE.



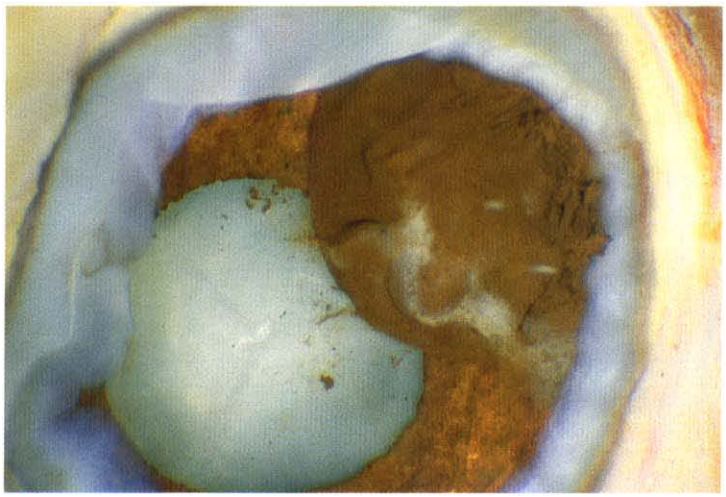
**15-16** Retinal atrophy
Narrow retina with absence of the rod and cone layer and disappearance of the outer nuclear layer. Only disorganized remnants of the inner nuclear layer remain. The ganglion cell layer is normal. Dog. HE.



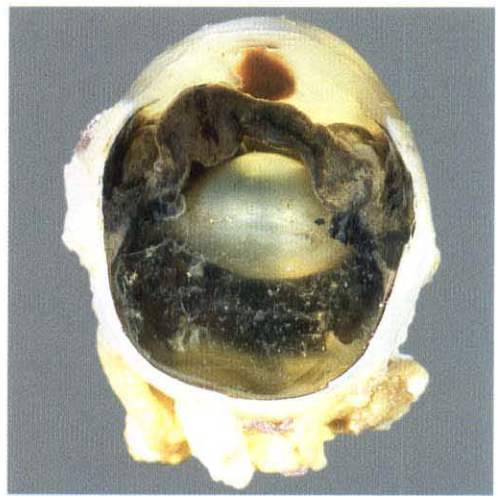
**15–17** Retinal detachment
Enucleated eye, sagittal section. Detachment of the retina. The retina remained attached to the *ora serrata* and the optical papilla only. Dog.



**15–18** Squamous cell carcinoma
Enucleated eye. Ulcerated neoplastic mass localized in the third eyelid. Cow.



**15–19** Melanoma (malignant)
Enucleated eye, frontal view. A circumscribed brown tumor in the iris. Dog.



**15–20** Melanoma (malignant)
Enucleated eye, sagittal section. Diffuse thickening of the iris with a tumor which has a dark-brown color. Cat.

# Chapter 16
# The ear



## THE EAR

The ear is composed of external, middle and internal components.

The main lesions consist of:

- congenital malformations;
- inflammation; and
- neoplasia.

Morphological alterations of the ear may result in vestibular dysfunction or deafness.

### *The external ear*

#### The pinna

***Skin disease***

Lesions of the pinna may be an extension of a generalized skin disease. The etiology of these skin diseases may be bacterial, parasitic, fungal, immune mediated or vascular.

***Swellings***

Swellings caused by trauma (such as *othematoma*) and *abscesses* most frequently occur in cats, dogs and pigs.

***Neoplasia***

*Neoplasms* of the pinna are similar to those occurring as skin tumors. Histiocytoma and mast cell tumors are common in dogs. White cats are susceptible to squamous cell carcinomas.

#### The external ear canal

***Proliferative otitis externa***

In the external canal of the ear a condition called *proliferative otitis externa* frequently occurs. This inflammatory condition is characterized by hyperplasia of the sebaceous and ceruminous glands, which occasionally are cystic.

Proliferative inflammation can produce solitary round polyps in the ear canal, most often in dogs.

***Neoplasia***

In the ear canal, ceruminous gland adenomas or carcinomas are common, along with papillomas and squamous cell carcinomas.

### *The middle ear*

***Otitis media***

*Otitis media* may be a sequel to otitis externa or may be induced by iatrogenic causes.

***Tympanic rupture***

Tympanic rupture may be a complication of otitis externa. In cats the most common cause of tympanic rupture is a *middle ear polyp*, which invades the external ear.

### *The inner ear*

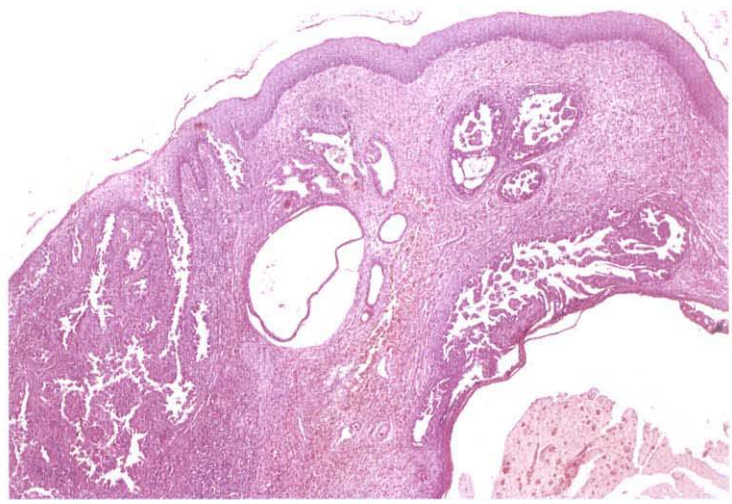
***Labyrinth damage***

*The inner ear labyrinth* may be damaged due to *labyrinthitis* (often the sequel of an otitis media), *ototoxicity*, *trauma*, or other sequelae of a middle ear disease.

**16-1** Chronic otitis externa
Chronic inflammation of the external ear canal with narrowing of the lumen caused by polypous proliferations. Dog.

**16-2** Chronic otitis externa
External ear canal (cross-section). Predominantly proliferative inflammation with infiltration of mononuclear cells (macrophages, lymphocytes, plasma cells) and some granulocytes and fibrosis. There is hyperplasia of sebaceous and ceruminous glands. The ceruminous glands have cystic dilation and are filled with eosinophilic homogeneous debris and inflammatory cells. Dog. HE.

**16-3** Suppurative otitis media
Ventral view of the skull, after dissection of the ventral wall of the *bulla tympani*. Both bullae are filled with purulent exudate. *Streptococcus canis* infection. Kitten.



**16-4** Ceruminous gland carcinoma
External ear canal (cross-section). Tumorous proliferation of ceruminous gland epithelium. Infiltration of tumor cells into the superficial squamous epithelial layer. In addition there is a slight mononuclear cell infiltration. Cat. HE.

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